Met-Ocean data sets:
climate, reanalysis, forecast and in situ data

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UCA Universidad de Cádiz

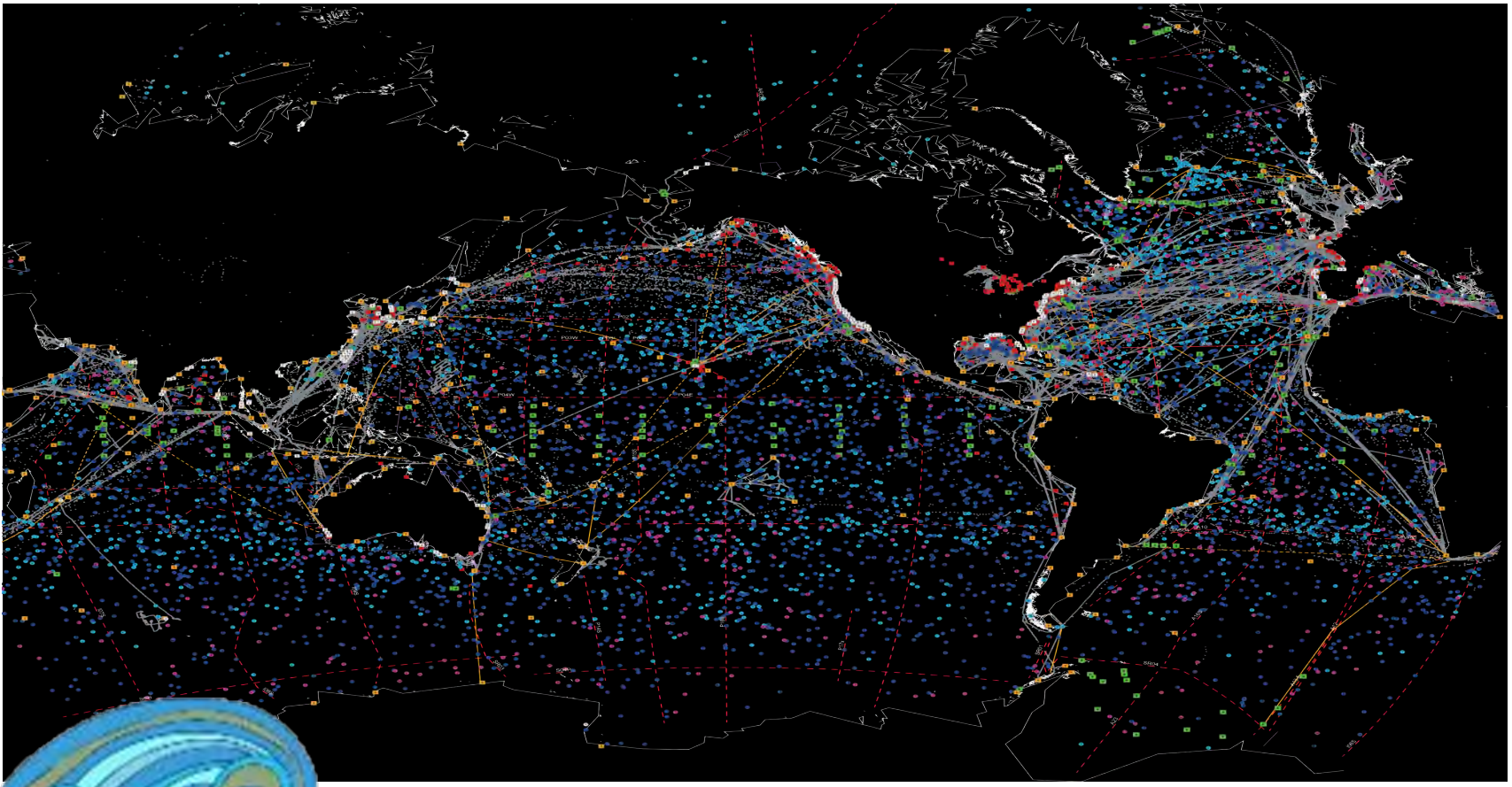
SEA EU European University of the Seas

Contents

- Met-Ocean data types and characteristics
- Analysis, reanalysis and climatology
- Overview of some data sets
- Some CMEMS products description (PHYS and INSITU)
- Data lexicon: quality information and product user manual

Metocean data

Meteorology and ocean physics data. Part of the Earth System data.



Ocean observing system report card 2021

At present a quite complete observing system (in situ and remote).

Not evenly distributed obs, fewer back in time.

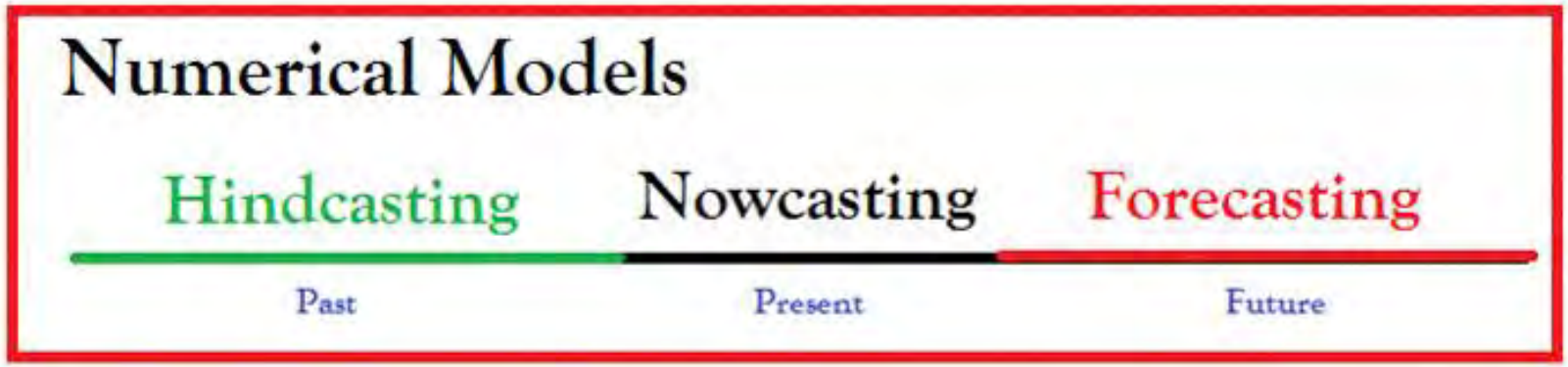
We need a long and reliable record for:

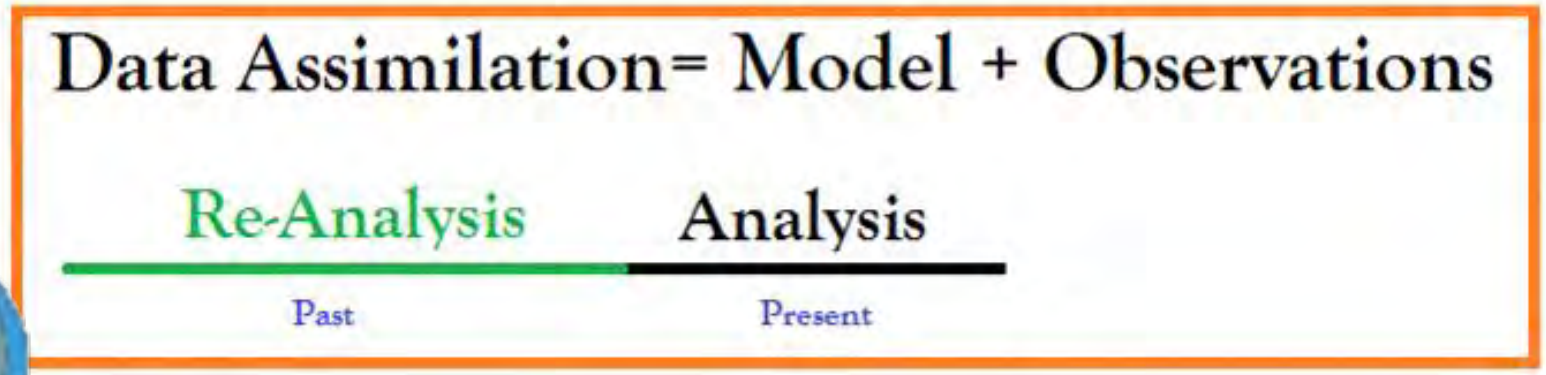
✓Climate change

✓Ocean health

✓Forecast and warning

Metocean data types (products)





From Siva Reddy PhD Thesis (2015) DOI:10.13140/RG.2.1.4459.4326

Metocean data types (level of processing)

Level 0
- Unprocessed instrument data

Level 1
- Data processed to sensor unit

Level 2
- Derived geophysical variables (same resolution and location as L1)

Level 3
- Georeferenced data (gridded fields)

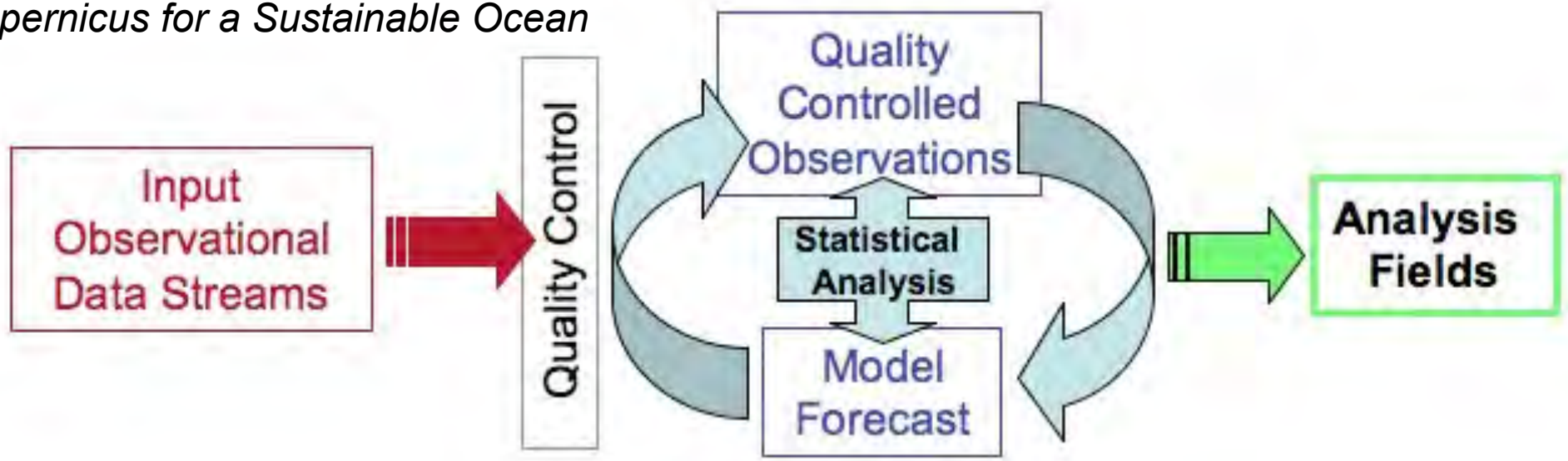
Level 4
- Model output or results from analysis of multiple lower level products, missing data gaps filled

Re/analysis products

An **analysis** is a snapshot of the **state of the ocean** at any **given time**. It is done using a **model, data and observations** to provide a best fit produced **on the fly**.

An oceanographic **reanalysis** consists in modelling **the state of the ocean over a long period of time** (several years) while correcting it with the **best available past observations**.

From the Blue Book Copernicus for a Sustainable Ocean

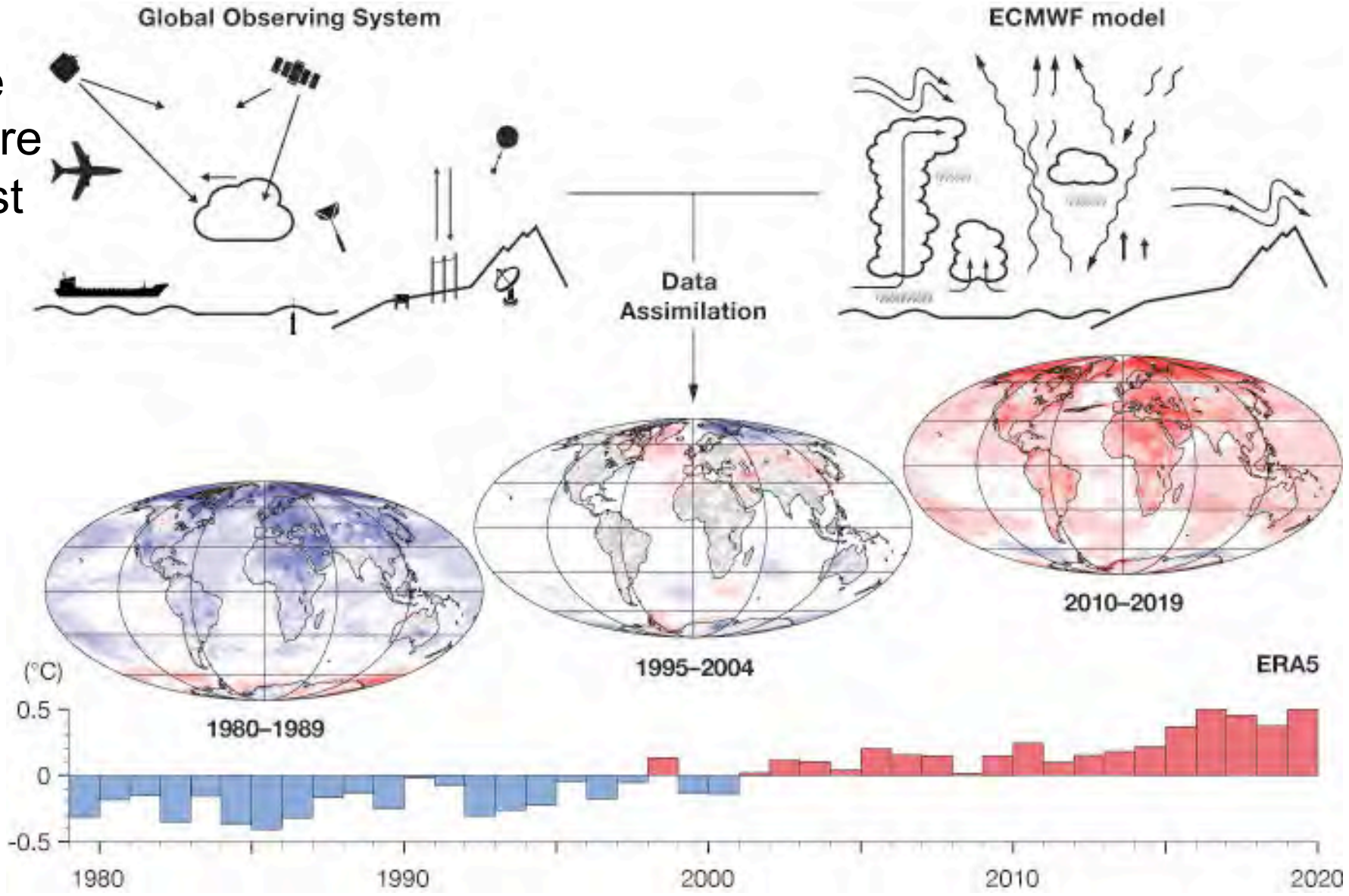


From E. Kalnay, www2.atmos.umd.edu

Re/analysis data

Reanalysis data provide the most complete picture currently possible of past weather and climate.

‘Maps without gaps’.



https://www.ecmwf.int/en/about/media-centre/focus/2020/fact-sheet-reanalysis

Re/analysis data: uncertainty

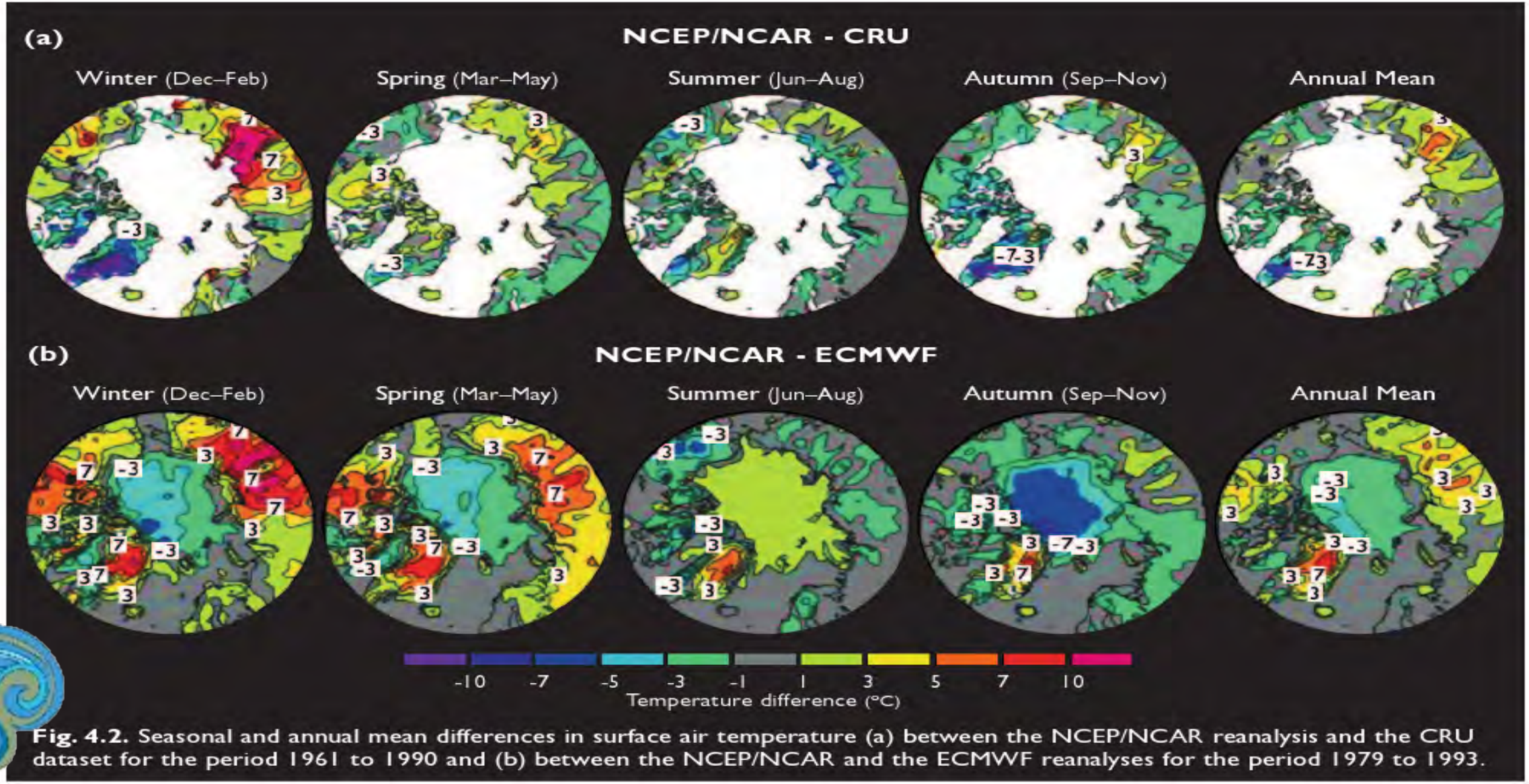
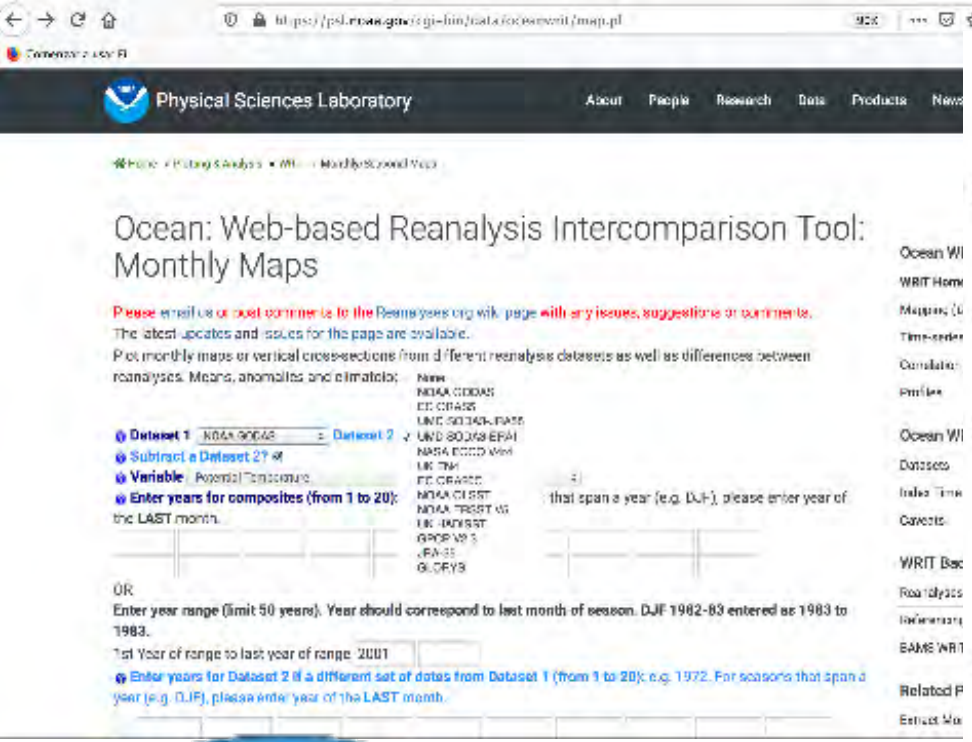
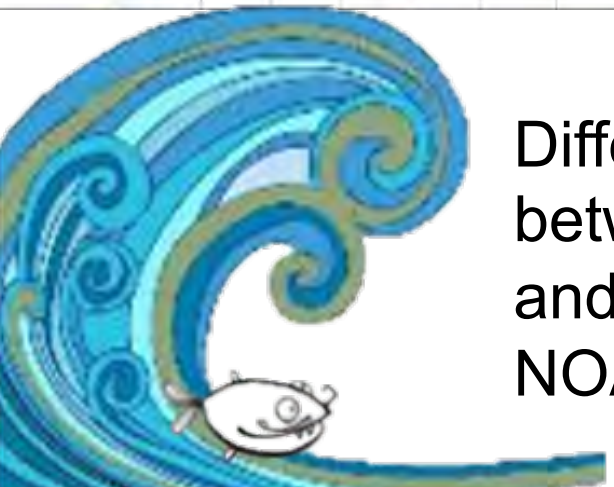


Fig. 4.2. Seasonal and annual mean differences in surface air temperature (a) between the NCEP/NCAR reanalysis and the CRU dataset for the period 1961 to 1990 and (b) between the NCEP/NCAR and the ECMWF reanalyses for the period 1979 to 1993.

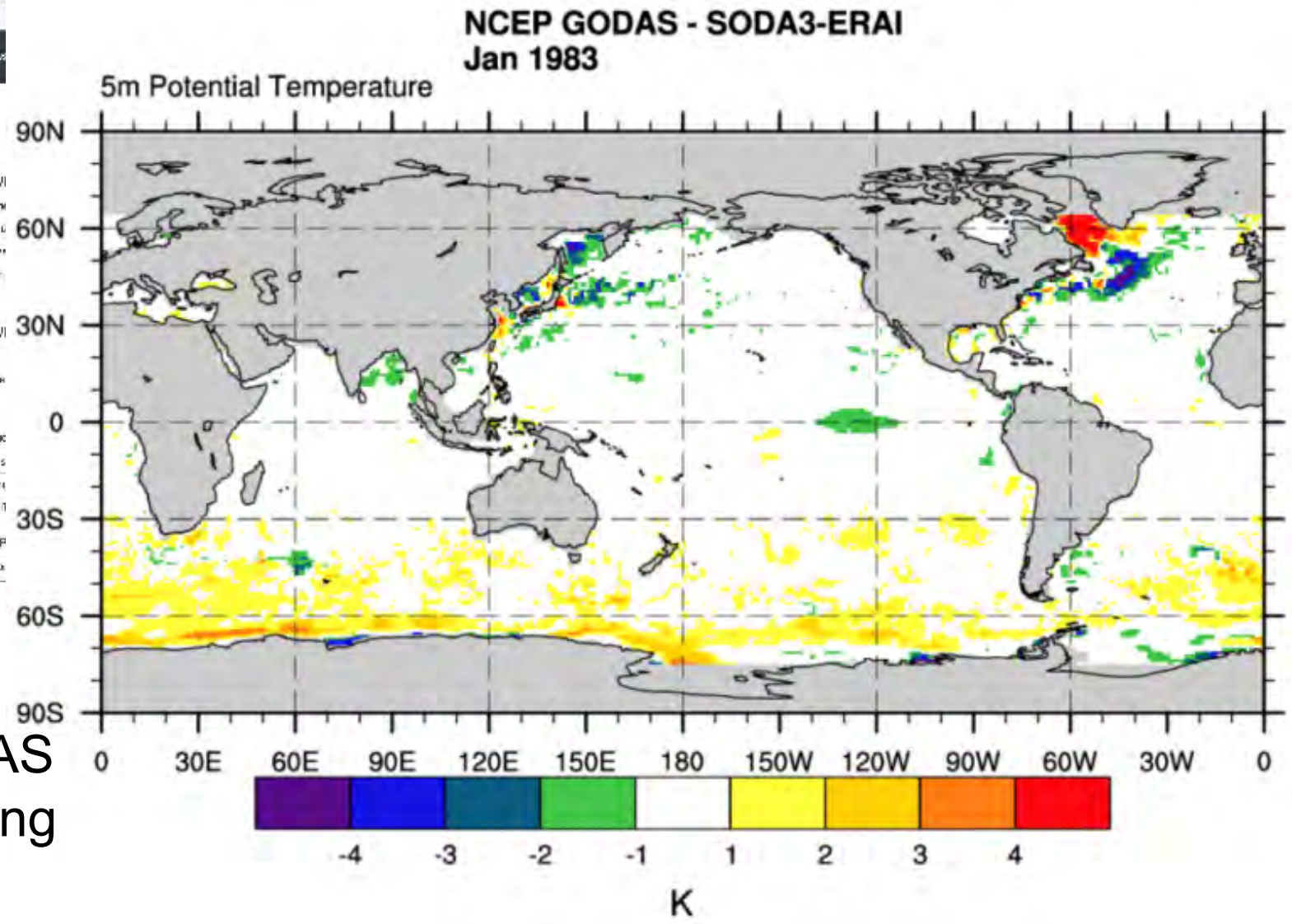
ACIA Report 2004

Re/analysis data: uncertainty

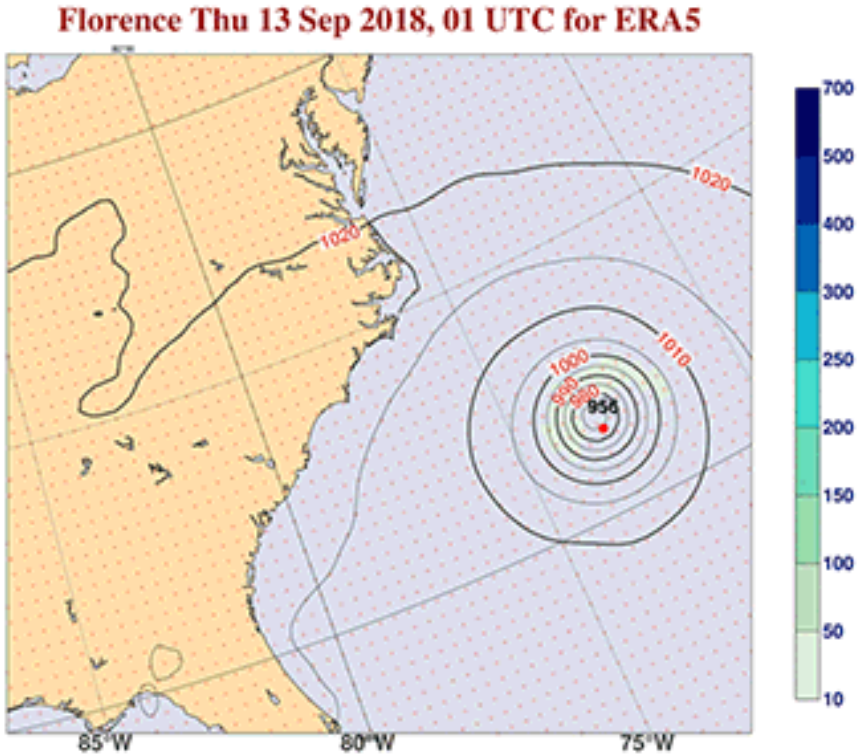


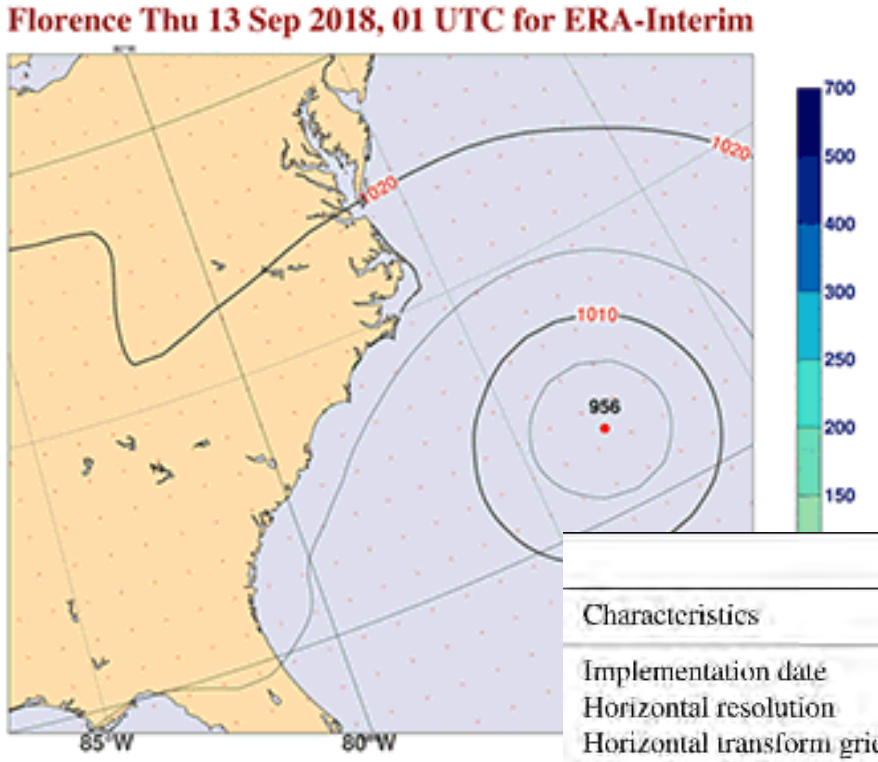


Differences between GODAS and SODA3 using NOAA WRIT



Reanalysis data: improving accuracy





From: https://www.ecmwf.int/en/about/media-centre/news/2018/ecmwfs-era5-reanalysis-soon-extend-back-1979

	ERA5	ERA-Interim
Characteristics		
Implementation date	8 Mar 2016	12 Dec 2006
Horizontal resolution	T_L639 (~ 31 km)	T_L255 (~ 79 km)
Horizontal transform grid[a]	0.3° × 0.3°	0.75° × 0.75°
Vertical resolution	137 levels up to 0.01 hPa	60 levels up to 0.1 hPa
Temporal resolution	Hourly	6-hourly
IFS cycle[h]	41r2	31r2
Period covered	1950–now	1979–now
Reference	Hersbach and Dee (2016)	Dee et al. (2011)
Resource requirements		
CPU time (s)	3130	350
Main memory (MB)	5800	530
Disk storage (GB)	450	5.8

From Hoffman et al. (2019) https://acp.copernicus.org/articles/19/3097/2019

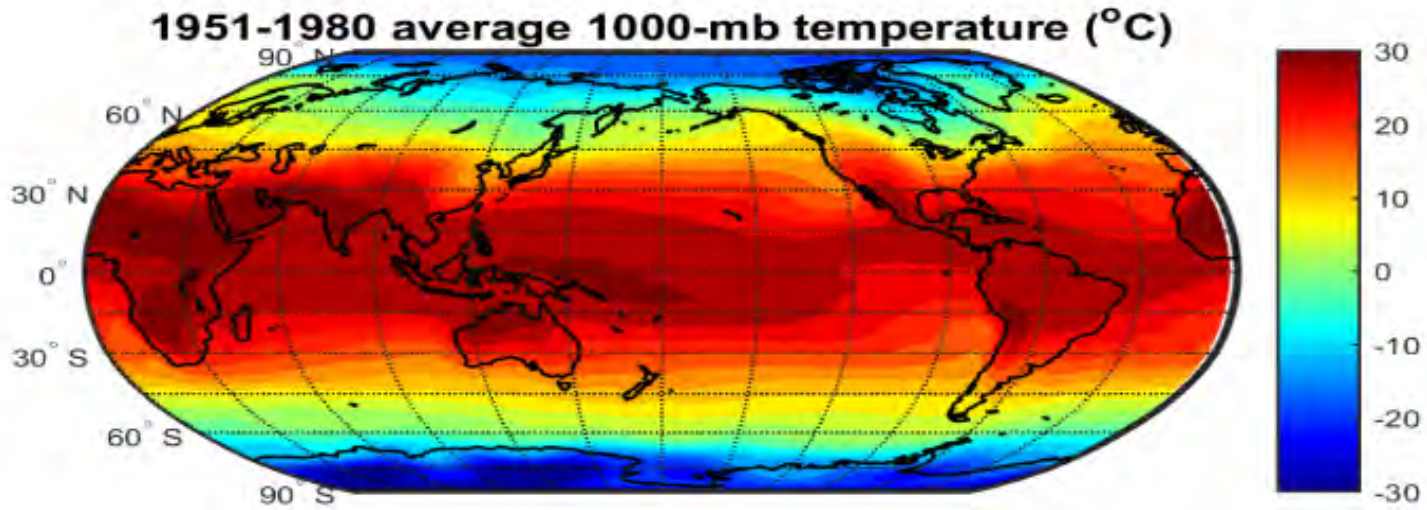
Climatology data

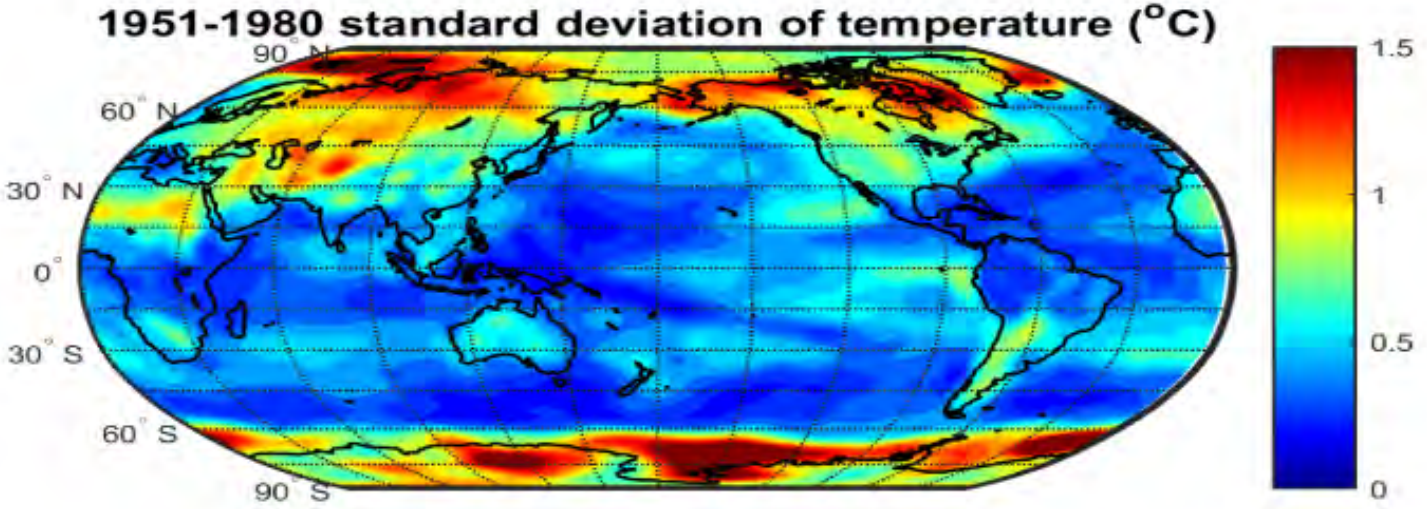
Climate is the statistical ensemble of states occurring in the system Atmosphere-Ocean-Solid Earth in a period of several decades (Monin, 1979).

Climate may be defined as the multivariate, multiple-time probability distribution of status of the ocean-ice-atmosphere system (North et al. 1982).

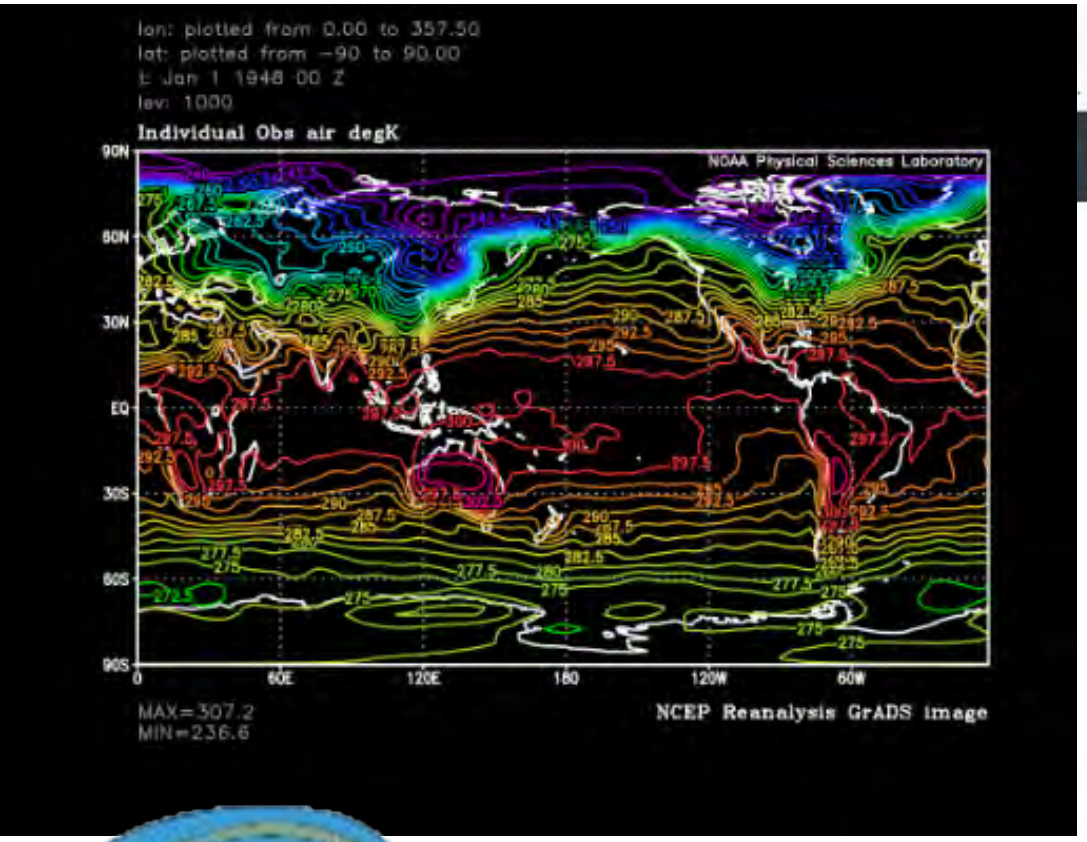
Climate normals: Period averages computed for a uniform and relatively long period comprising at least three consecutive ten-year periods (WMO No-1203).

Climate includes arithmetic **mean**, but it can also include values such as the **standard deviation**, percentile points, number of exceedances of a threshold or **extreme values.**

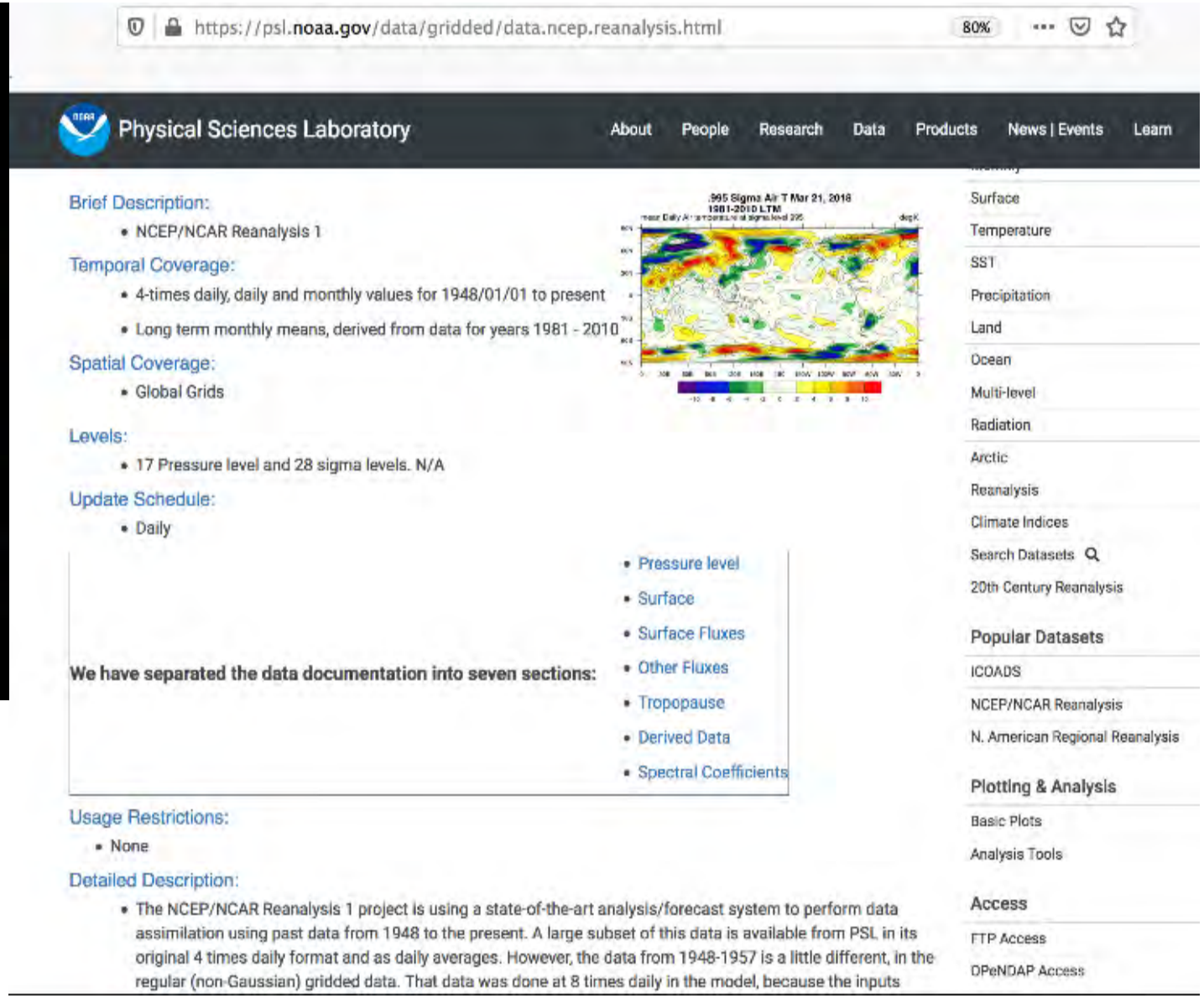




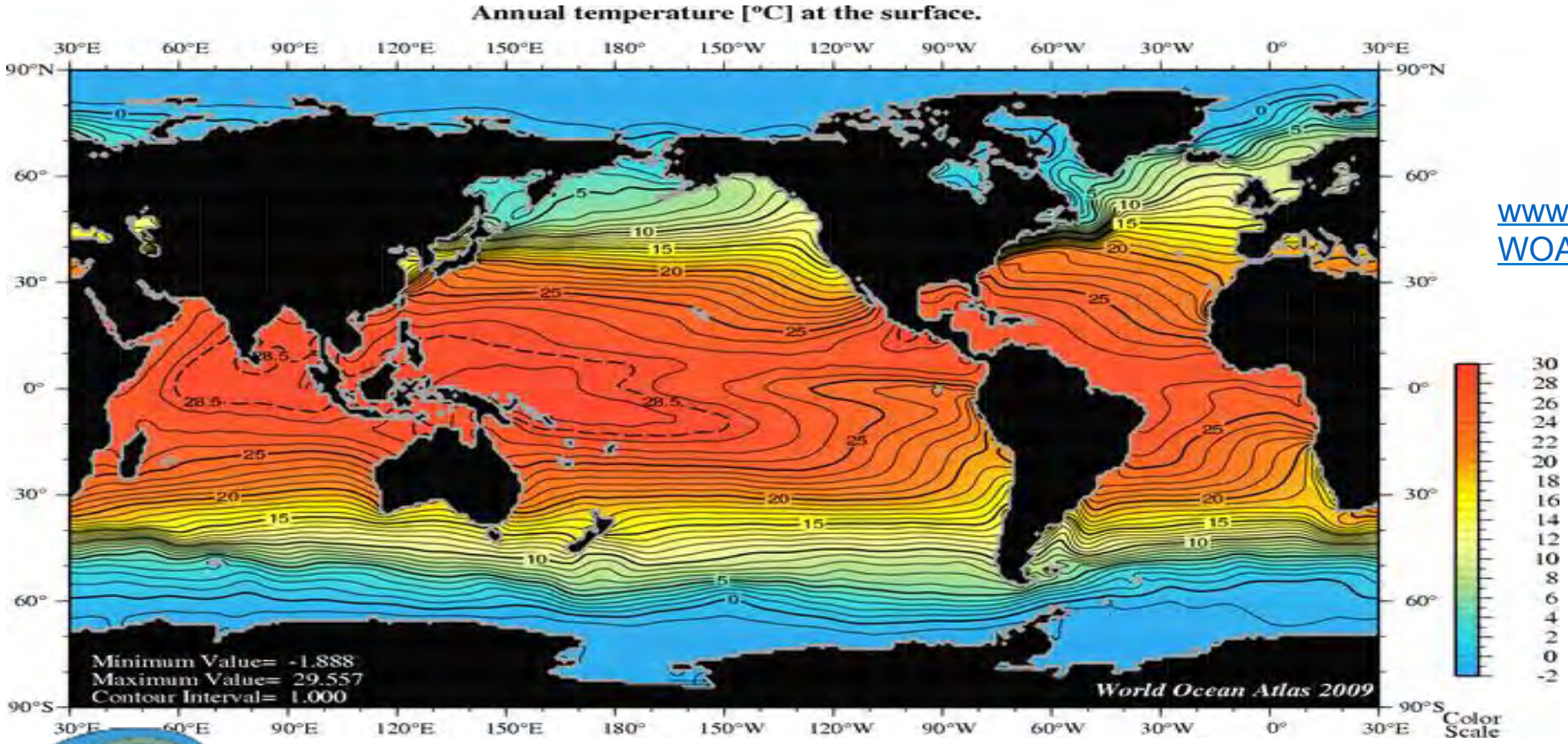
NCEP/NCAR Reanalysis 1



Air temperature at Surface
(January 1st 1948)
Resolution 2.5° x 2.5°



World Ocean Atlas 2009 (WOA09)

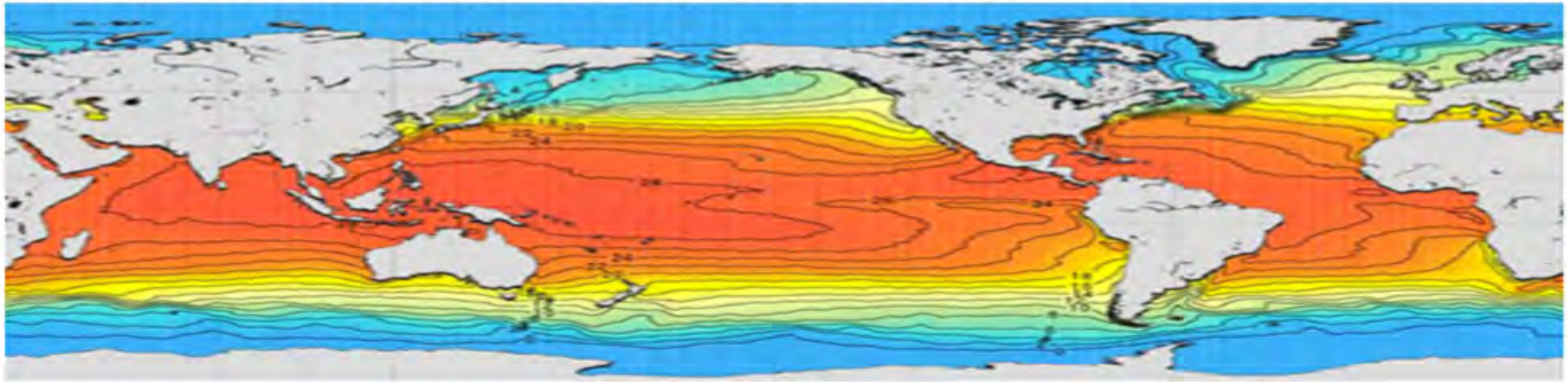


www.nodc.noaa.gov/OC5/WOA09/pr_woa09.html

World Ocean Atlas 2009 (WOA09) is a set of **objectively analyzed (1° grid)** climatological fields of **in situ temperature, salinity, dissolved oxygen, Apparent Oxygen Utilization** (AOU), **percent oxygen saturation, phosphate, silicate, and nitrate** at **standard depth levels** for **annual, seasonal, and monthly compositing periods** for the World Ocean. It also includes **associated statistical fields** of observed oceanographic profile data interpolated to standard depth levels on both 1° and 5° grids .

World Ocean Atlas 2018 (WOA18)

WORLD OCEAN ATLAS 2018 (WOA18)



The *WOA18* updates previous versions of the World Ocean Atlas to include approximately 3 million new oceanographic casts added to the World Ocean Database and renewed quality control.

This final version of WOA18 published in July, 2019 is replacing a prereleased version made available in September, 2018. The changes between the versions include:

1. For the first time the Animal mounted pinniped temperature profiles (APB) have been added improving coverage in high latitude areas.
2. A different Expendable Bathythermograph (XBT) correction (Cheng et al., 2014) has been employed.
3. A double XBT correction has been detected in pre-release version and fixed in final version.
4. All temperature and salinity climatological fields were re-calculated to account for these adjustments.

https://www.ncei.noaa.gov/access/world-ocean-atlas-2018/

World Ocean Atlas 2018 (WOA18)

https://www.ncei.noaa.gov/access/world-ocean-atlas-2018/

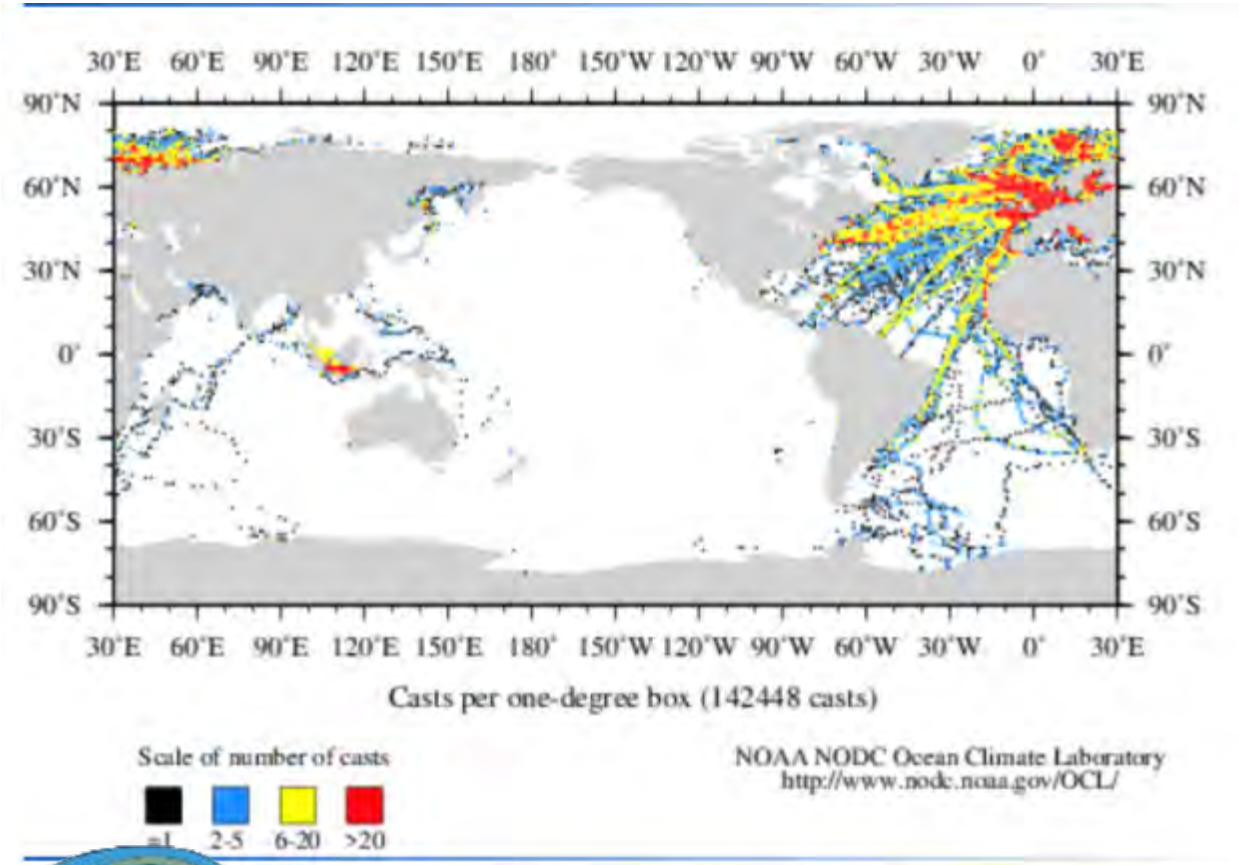
Table 1.3. Comparison of the number of oceanographic casts in WOD18 compared to previous WOD versions

Dataset	NCEI (1974)[1]	NCEI (1991)[2]	WOA94	WOD98	WOD01	WOD05	WOD09	WOD13	WOD18
OSD[3]	425,000	783,912	1,194,407	1,373,440	2,121,042	2,258,437	2,541,298	3,115,552	3,220,635
CTD[4]	na	66,450	89,000	189,555	311,943	443,953	641,845	848,911	1,029,231
MBT[5]	775,000	980,377	1,922,170	2,077,200	2,376,206	2,421,940	2,426,749	2,425,607	2,430,807
XBT	290,000	704,424	1,281,942	1,537,203	1,743,590	1,930,413	2,104,490	2,211,689	2,303,354
MRB	na	na	na	107,715	297,936	445,371	566,544	1,411,762	1,585,135
DRB	na	na	na	na	50,549	108,564	121,828	251,712	227,871
PFL	na	na	na	na	22,637	168,988	547,985	1,020,216	1,867,873
UOR	na	na	na	na	37,645	46,699	88,190	88,190	127,544
APB	na	na	na	na	75,665	75,665	88,583	1,713,132	1,804,605
GLD	na	na	na	na	na	338	5,857	103,798	1,148,669
Total casts	**1,490,000**	**2,535,163**	**4,487,519**	**5,285,113**	**7,037,213**	**7,900,368**	**9,155,099**	**13,190,569**	**15,861,868**
Plankton	na	na	na	83,650	142,900	150,250	218,695	242,727	245,059
SUR[6]	na		na	na	4,743	9,178	9,178	9,289	9,289

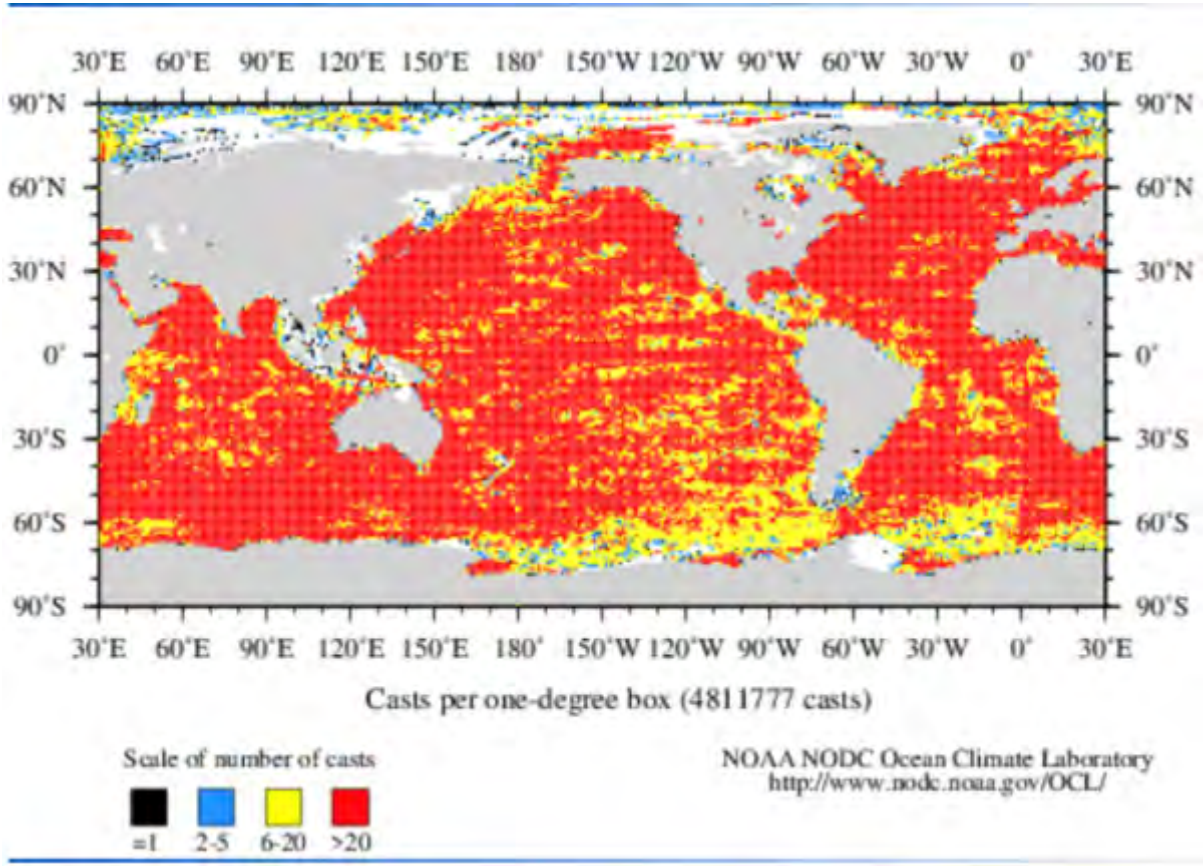
Boyer et al., 2018

World Ocean Database 2018 (WOD18)

https://www.ncei.noaa.gov/access/world-ocean-database-select/dbsearch.html

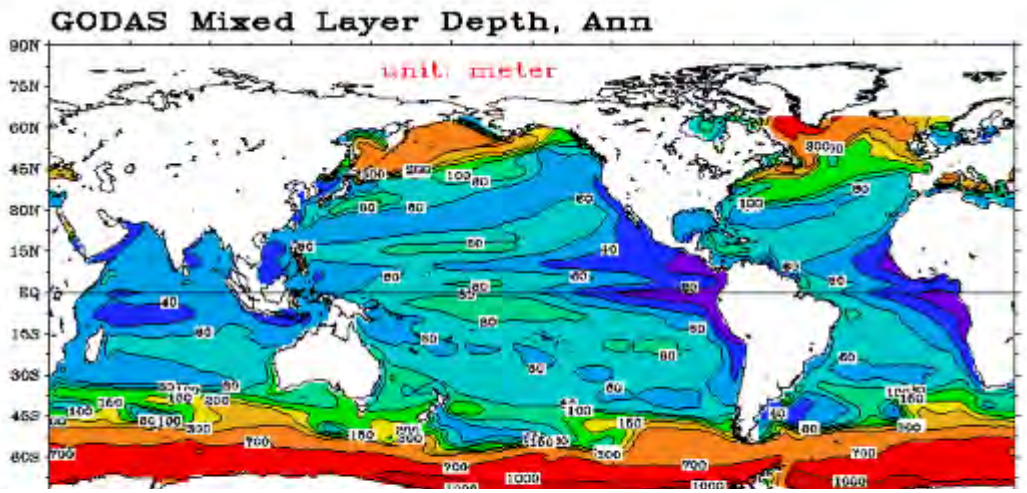


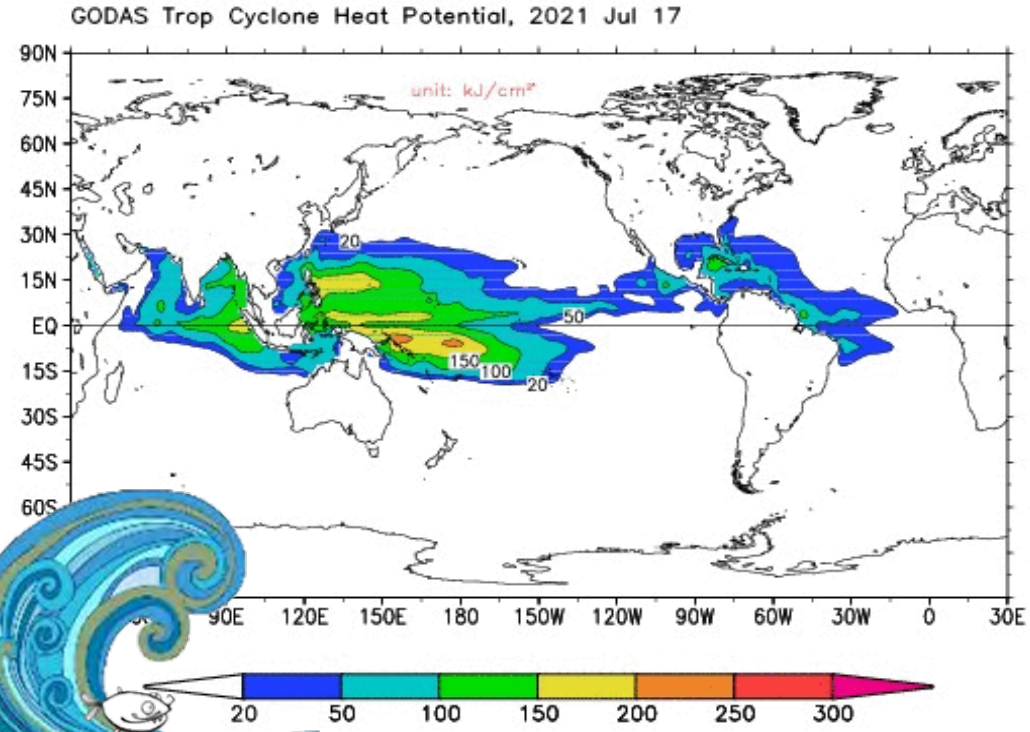
1910-1920



2010-2020

NCEP Global Ocean Data Assimilation System (GODAS)





https://www.cpc.ncep.noaa.gov/products/GODAS/

National Weather Service

Climate Prediction Center

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Climate Observation Division (COD)

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GODAS Home

Introduction

Climatology
Plots
Animations

Monthly Products
Plots
Animations

Pentad Products
Plots
Animations

Coastal Upwelling
Coastal upwelling

Binary Data
Monthly in GRB
Pentad in GRB
Monthly in NetCDF
Other formats

NCEP Global Ocean Data Assimilation System (GODAS)

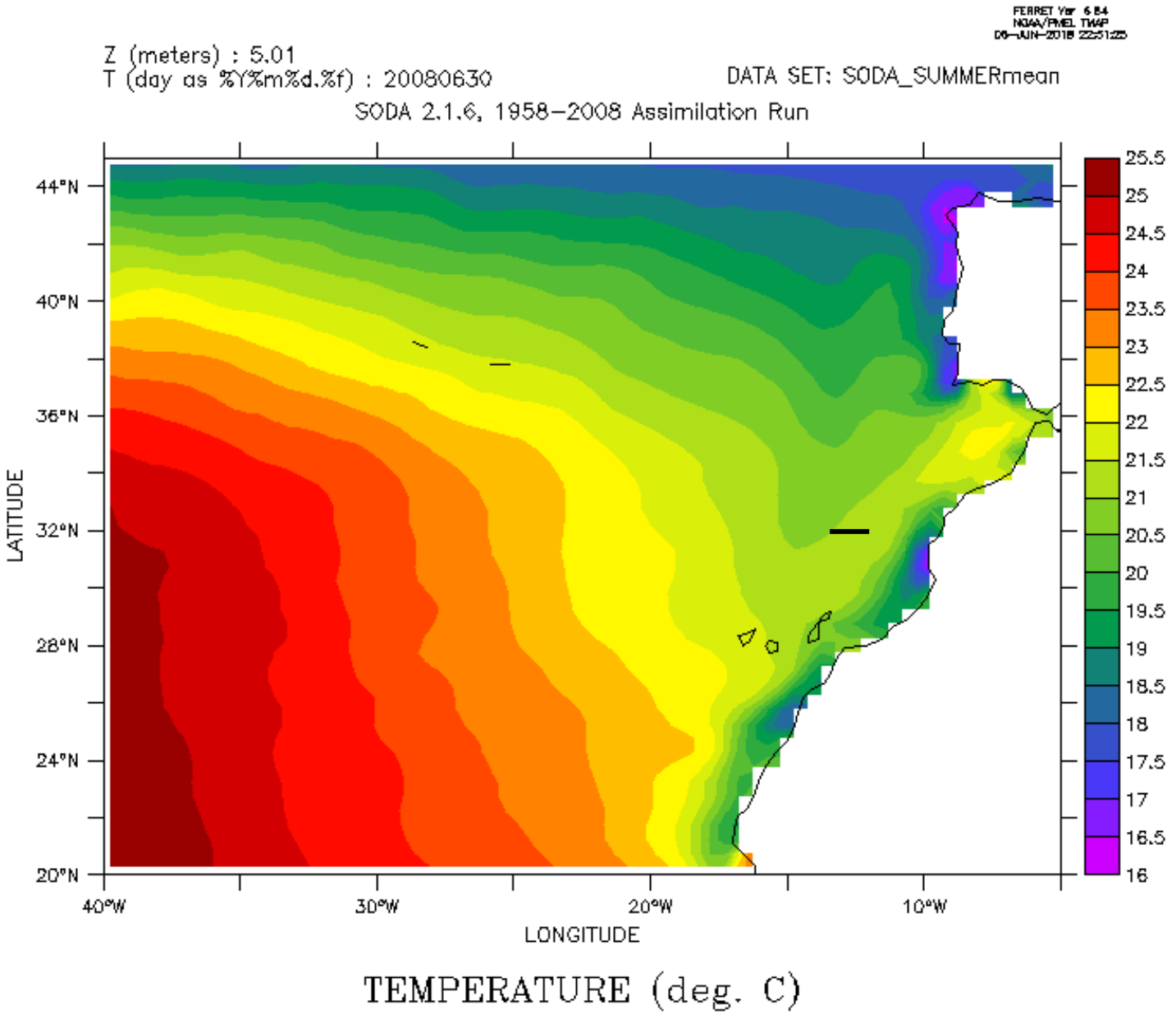
GODAS depends on continuous real-time data from the Global Ocean Observing System. This project is to deliver routine ocean monitoring products, and is being implemented by CPC in cooperation with NOAA Global Ocean Monitoring and Observing (GOMO)

- Introduction
- Climatology (1982-2004): Plots Animations
- Monthly products (1979-present): Plots Animations
- Pentad products (past 3 months): Plots Animations
- Coastal upwelling: Plot
- Ocean reanalysis for downloading: Monthly Pentad
- Validations against observations
- Links to other ocean analysis data

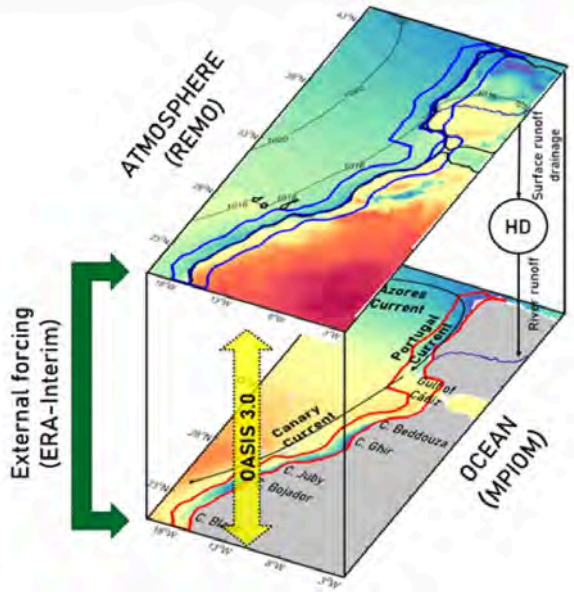
Monthly Ocean Briefing

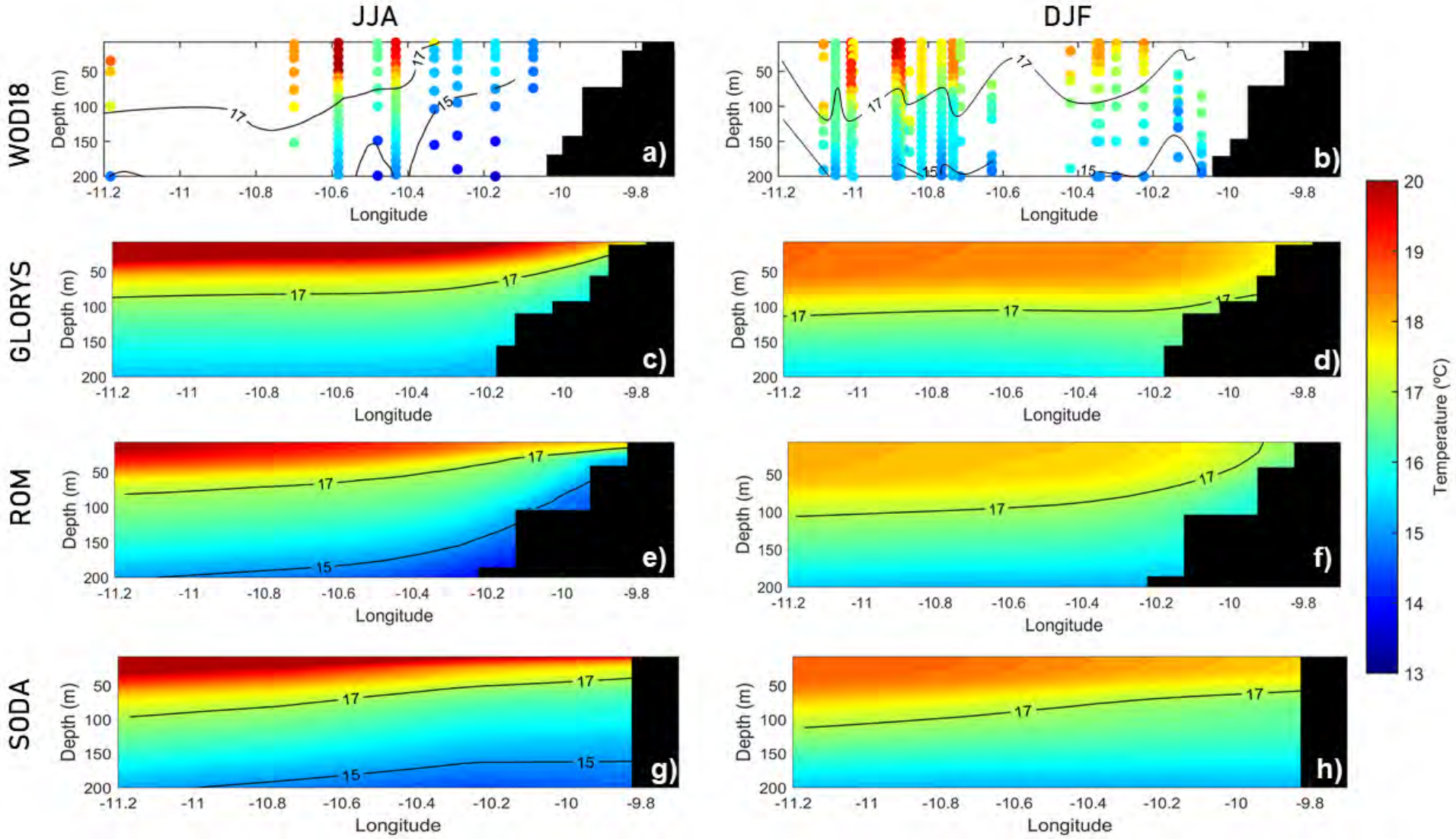
Simple Ocean Data Assimilation (SODA)

Model: GFDL MOM5/SIS1
Resolution: Horizontal 0.25° (28 km at Equator). 50 vertical levels, uper layer at 10 m depth
Period and time resolution: 1871-2008 (monthly), 1980-2017 (5 days)
Assimilated data: WOD09 T&S, ICOADS 2.5 SST
Forcings: 20CRv2 for wind stress and bulk formulae
https://www.soda.umd.edu/



Insitu data, models and reanalysis



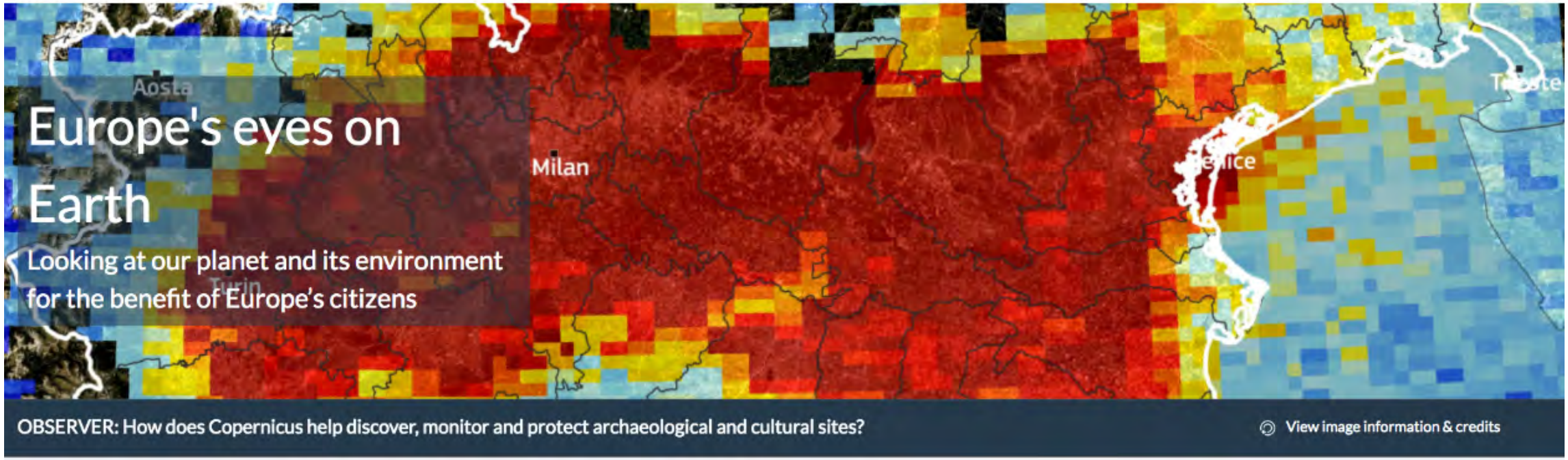


Temperature (ºC) transect for JJA (left) and DJF (right) in Cape Ghir (1980–2012) for WOD18 (**a**, **b**), GLORYS (**c**, **d**), ROM (**e**, **f**) and SODA (**g**, **h**). Vázquez et al. (2021)

MARINE DATA LITERACY COURSE

Copernicus
Europe's eyes on Earth

About Copernicus | Copernicus Services | Opportunities | Access to Data | Library | Use cases



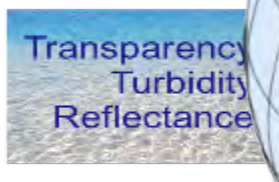
Copernicus Services

Atmosphere | Marine | Land | Climate Change | Security | Emergency

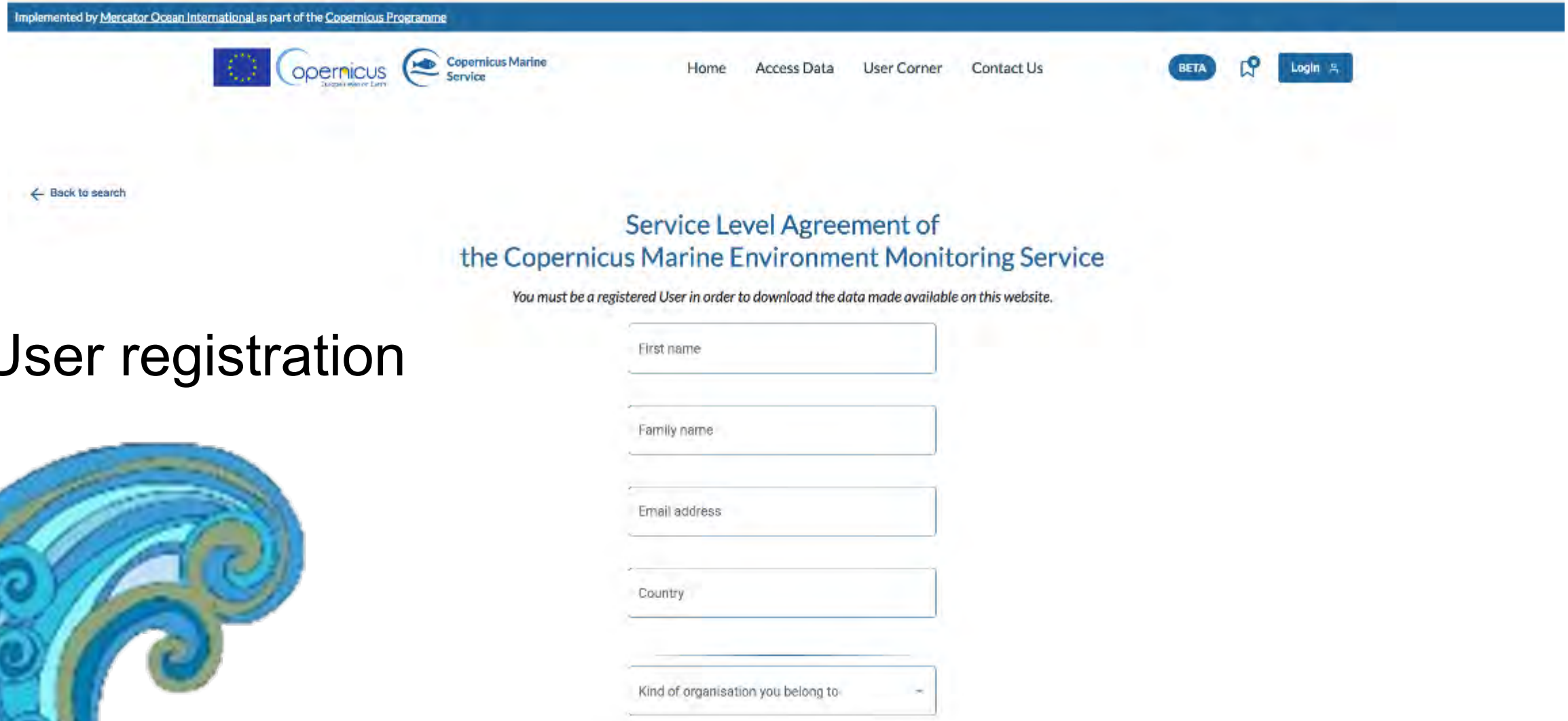
Copernicus Marine Environment Monitoring Service

CMEMS -An operational European service by European experts to offer the best worldwide information on Marine Environment based on observations and models

Domains: Global and 6 regional domains



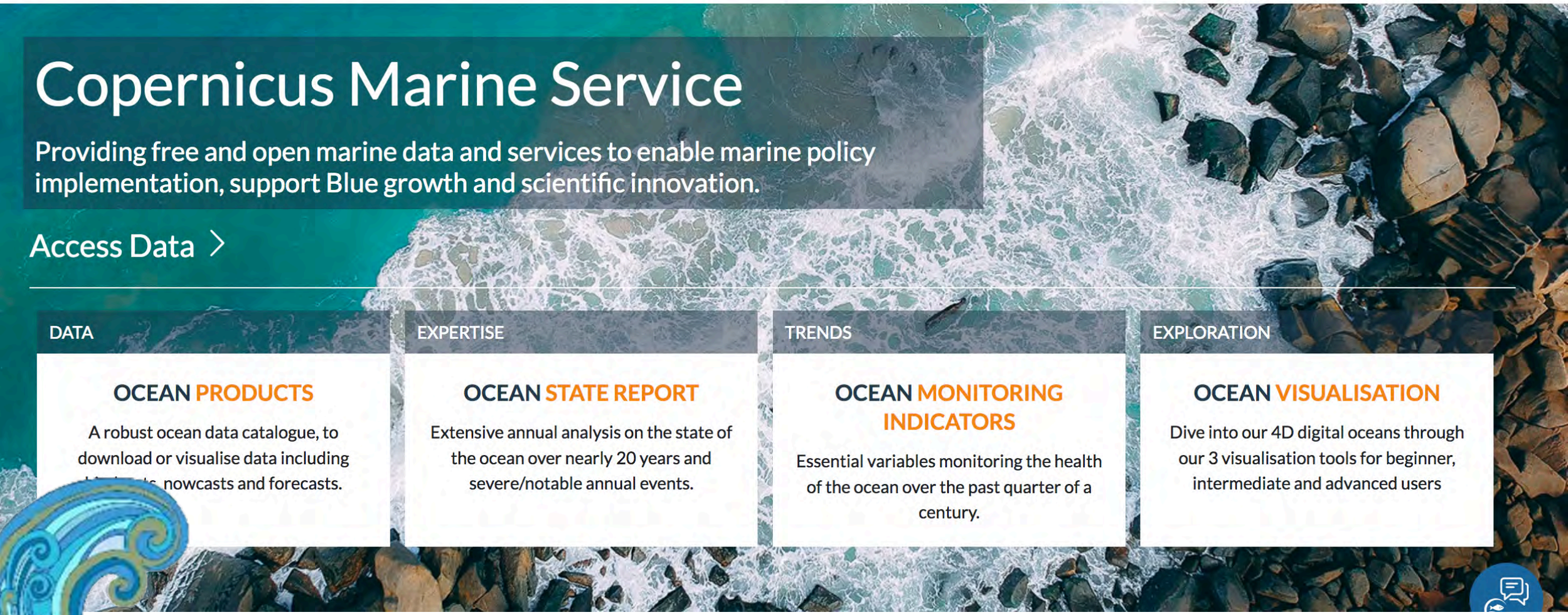
Copernicus Marine Environment Monitoring Service



User registration

https://resources.marine.copernicus.eu/registration-form

Copernicus Marine Environment Monitoring Service



Copernicus Marine Environment Monitoring Service

User Corner

Home > User Corner

Getting started

Are you new to our service? Find out everything you need to know to get operational.

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Have a question about our services? Find everything gathered in one intuitive place online.

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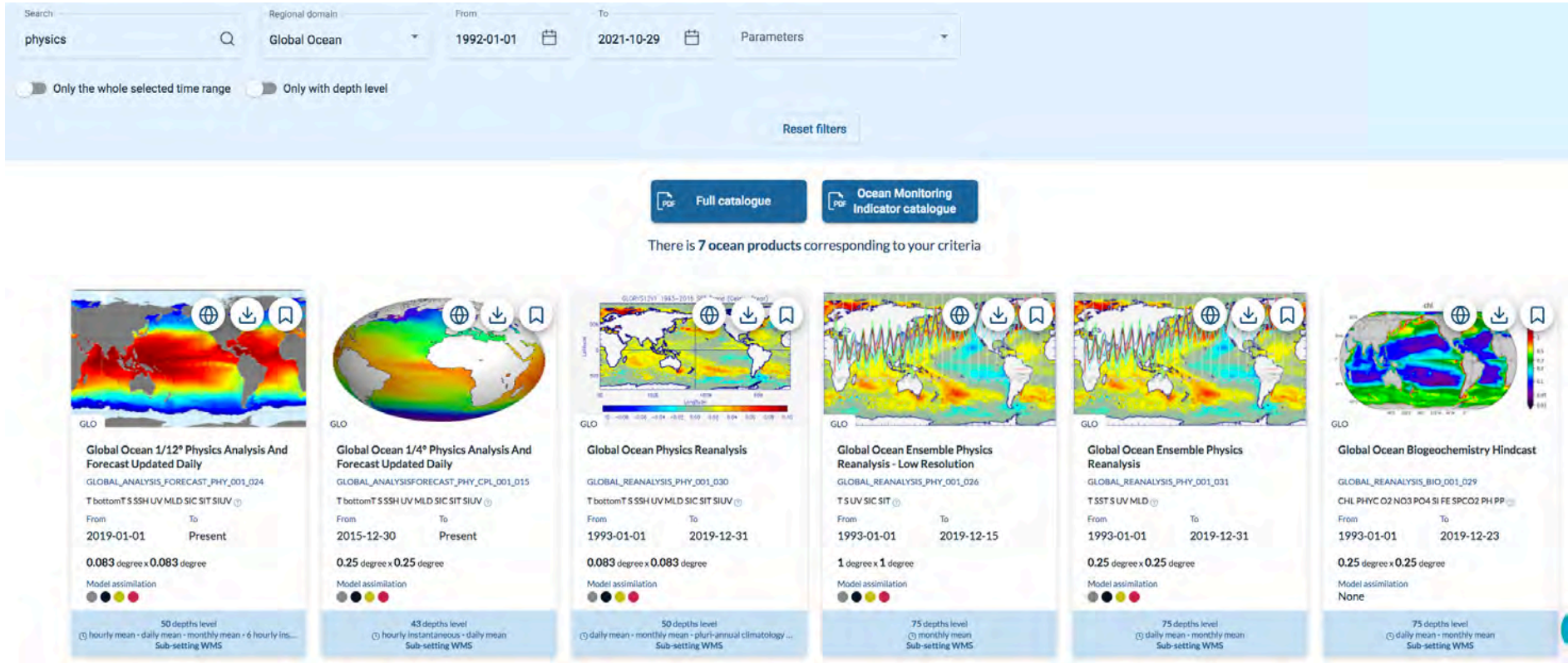
Transparency is needed to create trust and value: see a summary of key points associated

Copernicus Marine Environment Monitoring Service

Searching the catalogue:

- Keyword
- Domain
- Time period
- Parameters



Product

Datasets

Parameters

Resolution and coverage limited by:
- computing power
- storage capacity

You can download a pdf with the products corresponding to your search criteria, and an informative glossary

MARINE DATA LITERACY COURSE

GLOBAL - PHY

PRODUCTS			CHARACTERISTICS					
MODELS / OBSERVATION	TYPE (NRT / MY)	REFERENCES	PARAMETERS	HORIZONTAL AND VERTICAL RESOLUTIONS	TEMPORAL COVERAGE [START DATE; END DATE]	TEMPORAL RESOLUTION	UPDATE FREQUENCY	DATA ASSIMILED/ PROCESSING LEVEL
MODEL	NRT	001_015	T bottomT S SSH UV MLD SIC SIT SIUV	0.25° - 0.25° - 28km; 43 levels	[30/12/2015;ongoing]	Hinst + Dm	D	ITSP + SST + SIC and/or SIT + SL
	NRT	001_024	T bottomT S SSH UV MLD SIC SIT SIUV	0.083° - 0.083° - 9km; 50 levels	[01/01/2019;ongoing]	Hm + Dm + Mm + 6Hinst	D + M	ITSP + SST + SIC and/or SIT + SL
	MY	001_026	T S UV SIC SIT	1° - 1° - 111km; 75 levels	[01/01/1993;15/12/2019]	Mm	Y	ITSP + SST + SIC and/or SIT + SL
	MY	001_030	T bottomT S SSH UV MLD SIC SIT SIUV	0.083° - 0.083° - 9km; 50 levels	[01/01/1993;31/12/2019]	Dm + Mm + Y	Y	ITSP + SST + SIC and/or SIT + SL
	MY	001_031	T S UV MLD	0.25° - 0.25° - 28km; 75 levels	[01/01/1993;31/12/2019]	Dm + Mm	Y	ITSP + SST + SIC and/or SIT + SL
SATELLITE/ INSITU	MY	015_007	UV W	0.25° - 0.25° - 28km; 75 levels	[01/01/1993;31/12/2018]	Wm	Y	L4 Grid

Legend

TEMPORAL RESOLUTIONS	
INS	Instantaneous
IRR	Irregular
MINm	Minutes Mean
MINinst	Minutes Instantaneous
Hm	Hourly Mean
Hinst	Hourly Instantaneous

UPDATE FREQUENCIES	
Cont	Continual
H	Times Daily
D	Daily
W	Weekly
TwiceW	Twice Weekly
M	Monthly

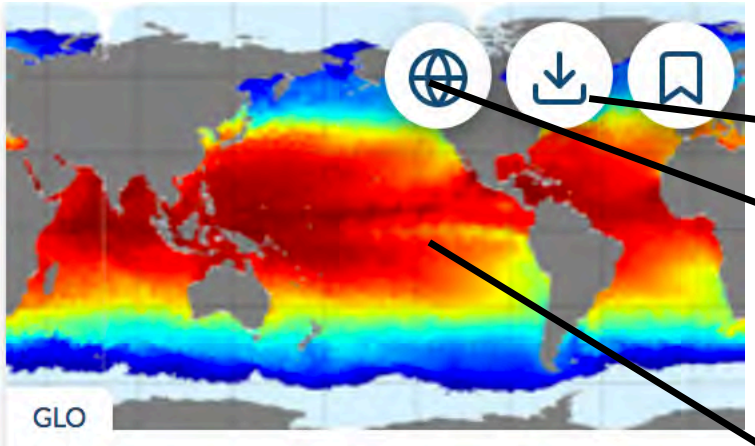
MODEL ASSIMILATIONS	
ITSP	In-Situ TS Profiles
NUTS	Nutrients (O2 N P)
CHL	Satellite Chlorophyll
SIC and/or SIT	Sea Ice Concentration and/or Thickness
SL	Sea Level
SWH	Sea Wave Height (SWH)

COLOR CELLS		
MODEL	#22689b	#79b6e2
INSITU	#f06542	#f6b4a2
SATELLITE	#57b279	#abd8bc
SATELLITE/ INSITU	#db57c3	#f3b9e8

Parameters acronyms (lexicon gets larger…)

Parameters (PHY/BIO/WAV)	Generic variable name	Acronyms	Specific variable name
Physical (PHY)	Temperature	T	Temperature
		SST	Sea surface temperature
		bottomT	Bottom temperature
		SSD	Sea surface density
		IST	Ice Surface Temperature
	Salinity	S	Salinity
		SSS	Sea surface salinity
		SSD	Sea surface density
	Sea surface height	SSH	Sea surface height
	Velocity	UV	Velocity
		UV	Geostrophic velocity
		UV	Barotropic velocity
		UV	Stokes drift
		UV	Tidal velocity
		W	Vertical velocity
	Mixed layer thickness	MLD	Mixed layer thickness
	Sea Ice	SIC	Sea ice concentration
		SIEDGE	Sea ice edge
		SITYPE	Sea ice type
Wave (WAV)	Wave	SWH	wave significant height
		MWT	wave mean period
		VMDR	wave mean direction
		VSDXY	Stokes drift
		WW	wind wave (period, height, direction)
		SW1	primary swell wave (period, height, direction)
		SW2	secondary swell wave (period, height, direction)
Biogeochemical (BIO)	Primary producers	CHL	Chlorophyll-a
		PP	Primary production
		PHYC	Phytoplankton
		PFT	Phytoplankton Functional Types
		PSC	Phytoplankton Sizes Class Types
	Low trophic level	ZOOC	Zooplankton
		PFT	Phytoplankton Functional Types
	Mid trophic level	MNKC	Micronekton
	Oxygen	O2	Dissolved oxygen
	Nutrients	NO3	Nitrate
		PO4	Phosphate

We select one of the products…



GLO

Global Ocean 1/12° Physics Analysis And Forecast Updated Daily

GLOBAL_ANALYSIS_FORECAST_PHY_001_024

T bottomT S SSH UV MLD SIC SIT SIUV

From 2019-01-01 To Present

0.083 degree x **0.083** degree

Model assimilation

50 depths level

hourly mean - daily mean - monthly mean - 6 hourly ins...

Sub-setting WMS

DOWNLOAD

VIEW

TITLE	ONLINE RESOURCE
Product User Manual (CMEMS-GLO-PUM-001-024)	
Quality Information Document (CMEMS-GLO-QUID-001-024)	

INFORMATION | DOCUMENTATION | SERVICES | NOTIFICATIONS

Product identifier
GLOBAL_ANALYSIS_FORECAST_PHY_001_024

Overview
Short description:

The Operational Mercator global ocean analysis and forecast system at 1/12 degree is providing 10 days of 3D global ocean forecasts updated daily. The time series start on January 1st, 2016 and is aggregated in time in order to reach a two full year's time series sliding window.

This product includes daily and monthly mean files of temperature, salinity, currents, sea level, mixed layer depth and ice parameters from the top to the bottom over the global ocean. It also includes hourly mean surface fields for sea level height, temperature and currents. The global ocean output files are displayed with a 1/12 degree horizontal resolution with regular longitude/latitude equirectangular projection.

50 vertical levels are ranging from 0 to 5500 meters.

This product also delivers a special dataset for surface current which also includes wave and tidal drift called SMOC (Surface merged Ocean Current).

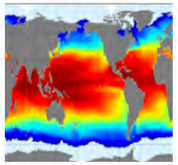
References
None

Variables
sea_water_potential_temperature (T)
sea_water_potential_temperature_at_sea_floor (bottomT)
sea_water_salinity (S)
sea_floor_depth_below_geoid (S)
sea_surface_height_above_geoid (SSH)
northward_sea_water_velocity (UV)

Areas : global-ocean

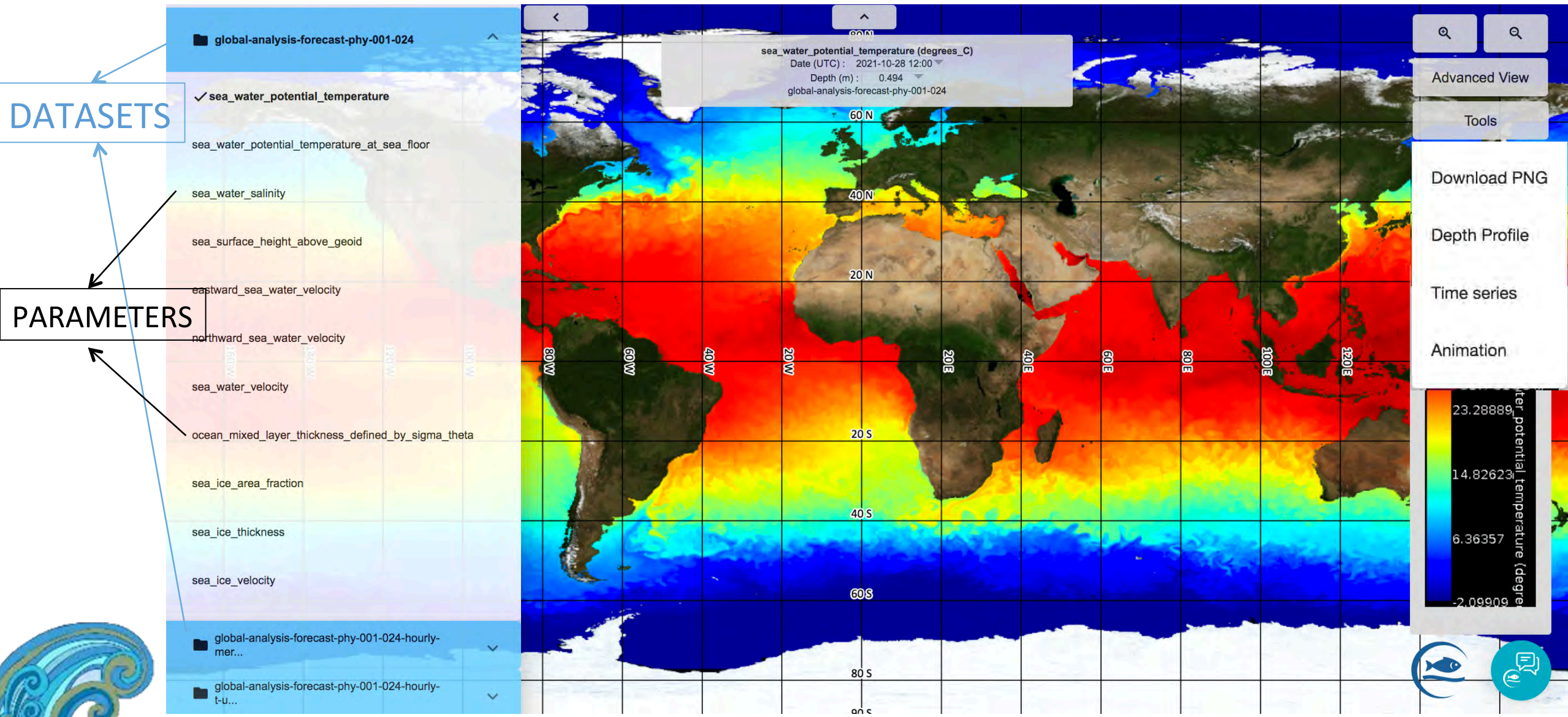
Geographical coverage

90
-180 180
-90

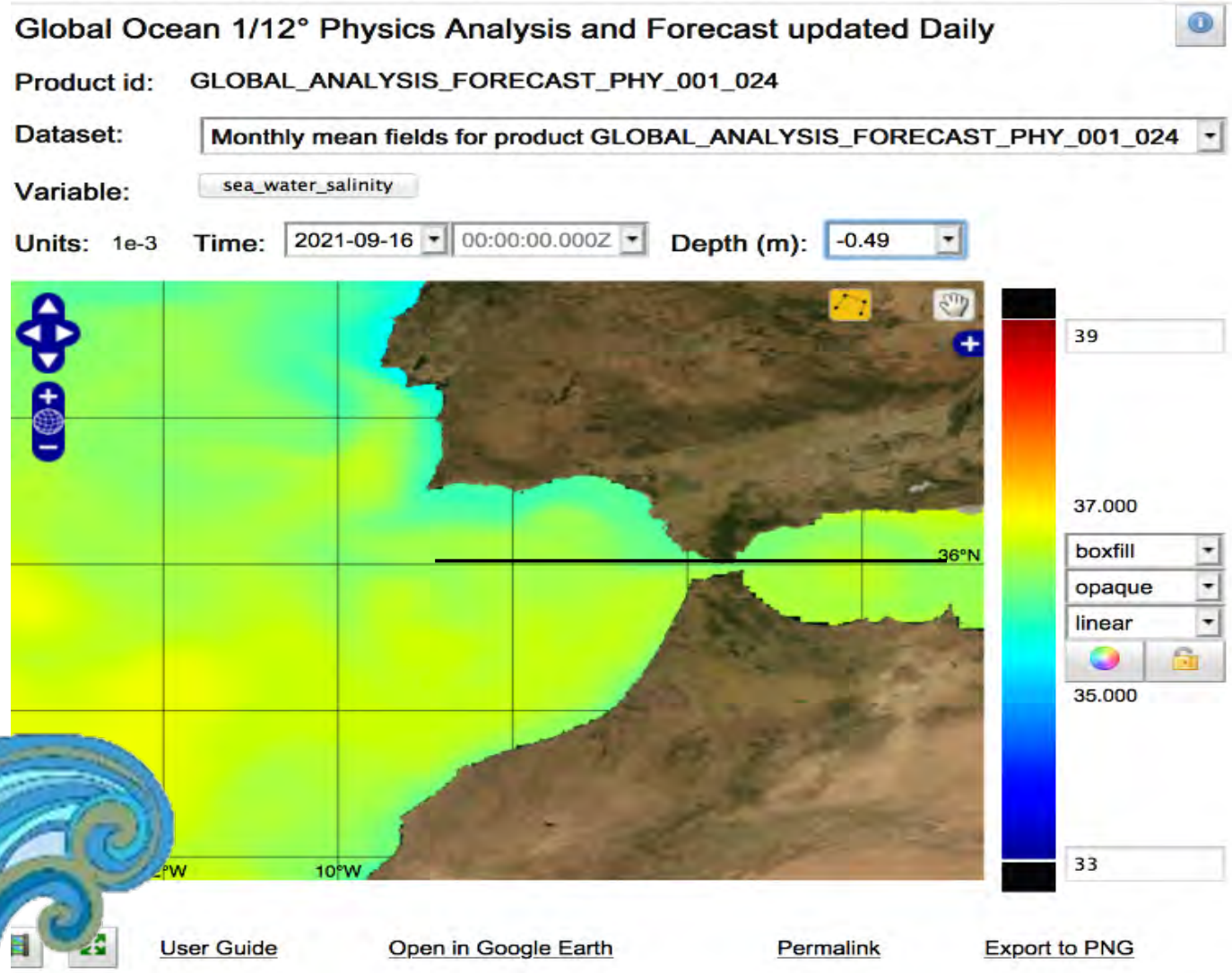


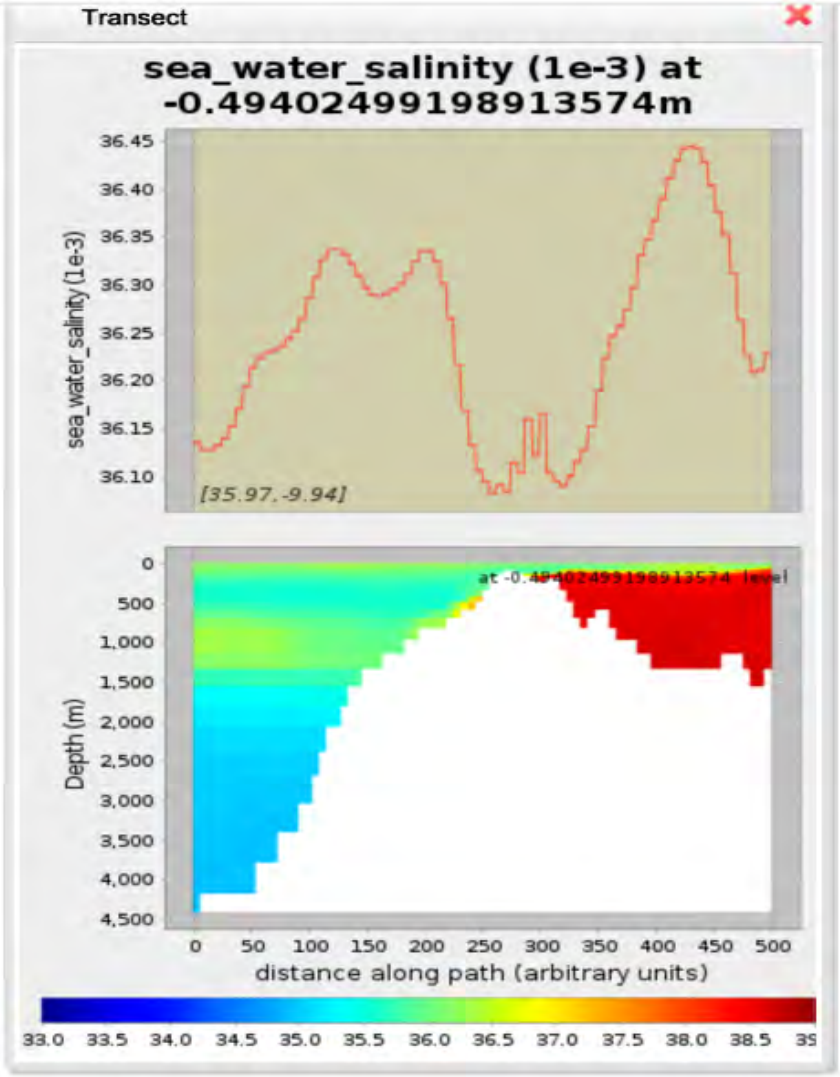
Observation / Models	numerical-model
Product type	near-real-time invariant* forecast
Processing level	L4
Data assimilation	Sea Level In-Situ TS Profiles Sea Ice Concentration and/or Thickness SST
Spatial resolution	0.083° × 0.083°
Vertical coverage (Number of vertical level)	from -5500 to 0 (50 levels)

We view one parameter from one of the datasets of the product …



We view one parameter from one of the datasets of the product …





PRODUCT USER MANUAL (PUM)

CHANGE RECORD

Issue	Date	§	Description of Change	Author	Validated By
1.1	21/09/2016	All	initial version	L.NOUEL	Y Drillet
1.2	19/09/2017	All	Addition of static and monthly datasets – Reformatting to follow new template	E. Fernandez	L. Nouel
1.3	26/04/2018	II.3	Addition of Information on SSH	C. Derval	C. Derval
1.4	18/01/2019		Addition of a new dataset of 3 merged : general circulation, tides & waves	S. Law Chune	C. Derval
1.5	19/11/2019		Addition of new datasets for instantaneous data	M. Tressol	
1.6	01/07/2020	IV	Nomenclature description & FTP download behaviour.	M. Tressol	C. Derval
1.7	03/05/2021		10D forecast for SMOC	C. Derval	C. Derval

CONSTANTLY UPDATED: EVOLVING SYSTEM, IMPROVING SERVICES

PRODUCT USER MANUAL (PUM)

MARINE DATA LITERACY COURSE

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Full description and how to use it

Dataset: global-analysis-forecast-phy-001-024--hourly-merged-uv		
Variables	Zonal and Meridional Velocities for : - Oceanic general circulation : (uo,vo) - Tide currents (utide, vtide) - Current from waves (ustokes, vstokes) - Total current (utotal, vtotal)	
	Analysis	**Forecast**
Update frequency	Daily	Daily
Available time series	1st April 2016 up to real-time	10-days forecast
Target delivery time	Daily at 12pm (noon) UTC	Daily at 12pm (noon) UTC
Temporal resolution	1-hourly instantaneous	1-hourly instantaneous
Number of vertical levels	1	
global-analysis-forecast-phy-001-024-3dinst-thetao		
Variables	- Temperature	
	Analysis	**Forecast**
Update frequency	Daily	Daily
Available time series	1st January 2019 up to real-time	48 hours forecast
Target delivery time	Daily at 12pm (noon) UTC	Daily at 12pm (noon) UTC
Temporal resolution	6-hourly instantaneous	6-hourly instantaneous
Number of vertical levels	50	

One product may have several datasets, each of which may have several parameters

QUALITY INFORMATION DOCUMENT (QUID)

COPERNICUS
MARINE ENVIRONMENT MONITORING SERVICE

QUALITY INFORMATION DOCUMENT

QUALITY INFORMATION DOCUMENT

For Global Sea Physical Analysis and Forecasting Product

GLOBAL_ANALYSIS_FORECAST_PHY_001_024

Issue: 2.1

Contributors :J-M. LELLOUCHE, O. LEGALLOUDEC, C.REGNIER, B. LEVIER, E. GREINER, M.DREVILLON

Quality Assurance Review Group : 30/04/2019

CHANGE RECORD

Issue	Date	§	Description of Change	Author	Validated By
1.0	23/09/2016	All	Creation of the document for CMEMS V2.3	M. Drevillon	Y. Drillet
2.0	19/10/2016		Correction after review	J. M. Lellouche	Y. Drillet
2.1	01/01/ 2019	SI,	Merging of the document to include SMOC dataset	S. Law Chune	Mercator Ocean

I.2 Executive summary

The quality of the Global high resolution system and GLO_HR products has been assessed using one year of the hindcast. The headline results for each of the variables assessed are as follows.

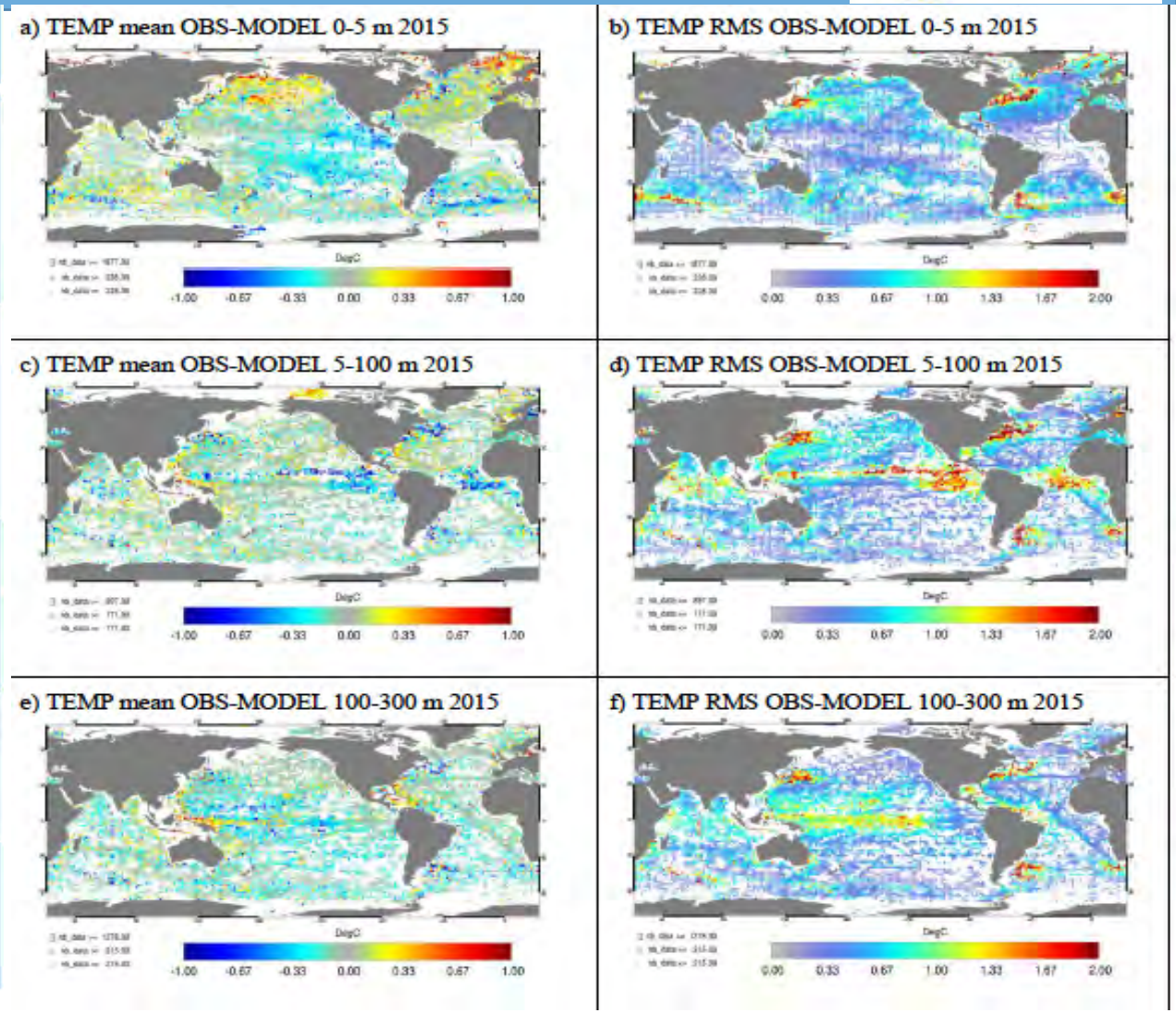
I.2.1 Temperature and salinity

The systems description of the ocean water masses is very accurate on average and departures from in situ observations rarely exceed 0.5 K and 0.1 psu. In the thermocline, RMS errors reach 1 K and 0.2 psu. In high variability regions like the Gulf Stream or the Agulhas Current, or the Eastern Tropica Pacific, RMS errors reach more than 2 K and 0.5 psu locally.

CONSTANTLY UPDATED: ASSESSMENT LEADS TO PRODUCT IMPROVEMENT

QUALITY INFORMATION DOCUMENT (QUID)

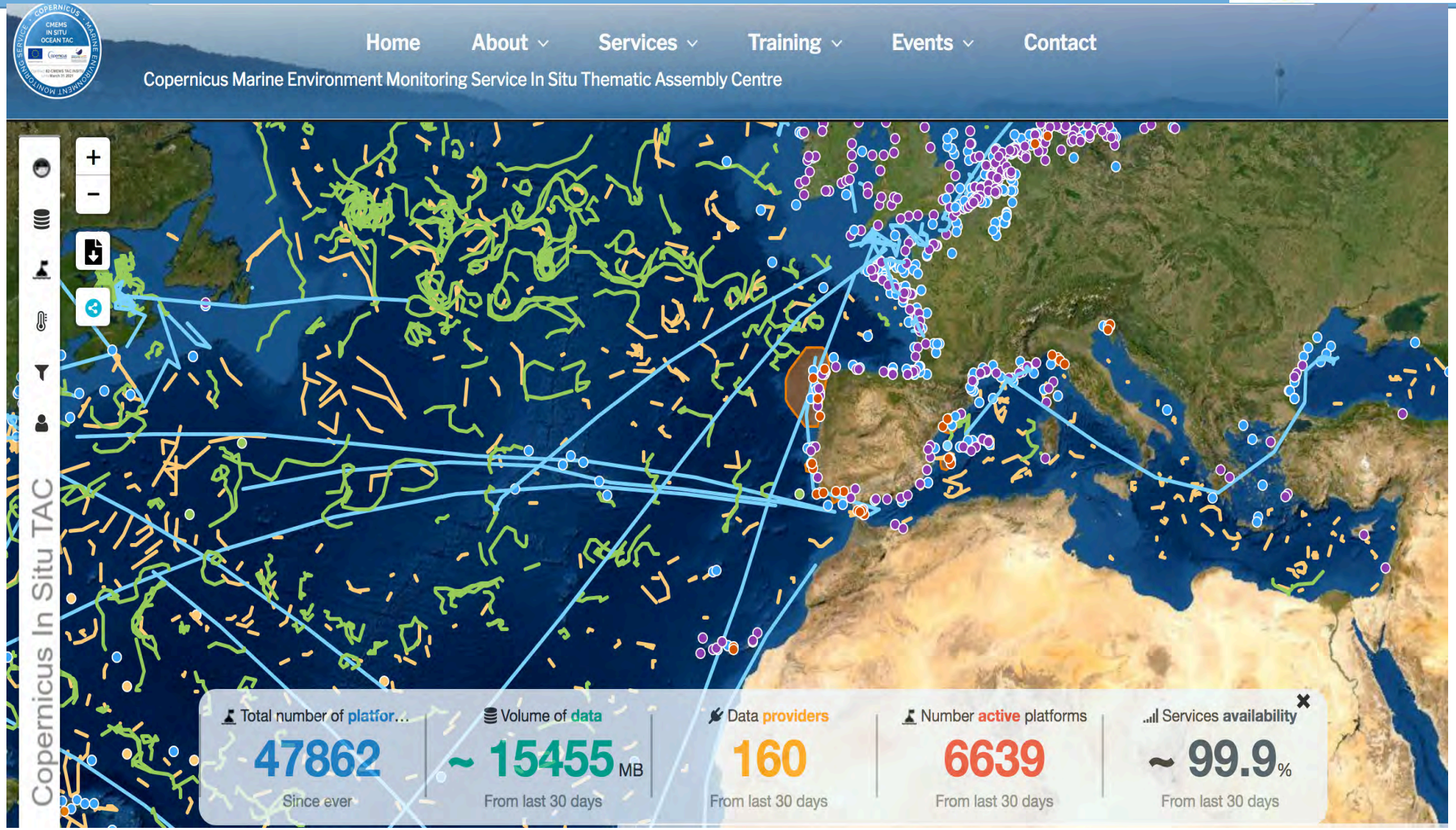
variable	Region	Type of metric	MERSEA/GODAE classification	Reference observational dataset
3D temperature	Global, and regional basins	Residual Error=obs-model Time evolution of RMS error on 0-500m Vertical profile of mean error.	CLASS4	CMEMS: CORIOLIS T (z) profiles
3D salinity	Global, and regional basins	Residual Error=obs-model Time evolution of RMS error on 0-500m Vertical profile of mean error.	CLASS4	CMEMS: CORIOLIS S(z) profiles
Sea level anomaly (SLA)	Global, and regional basins	Residual Error=obs-model Time evolution of RMS and mean residual error	Data assimilation statistics	CMEMS: On track AVISO sla observations from Jason3, Saral Altika and Cryosat
Sea surface height	At tide gauges (Global but near coastal regions)	Residual Error=model-obs Time series correlation and RMS error	CLASS4	Tide gauges sea level time series from GLOSS, BODC, Imedea, WOCE, OPPE and SONEL
Sea Surface Temperature SST	Global, and regional basins	Residual Error=obs-model Time evolution of RMS and mean error	Data assimilation statistics	CMEMS: OSTIA SST



Assessment metrics for different variables, using a large set of observations and reference climatologies

CMEMS IN SITU TAC

- Data filtering:
  Domain
  Platform
  Parameter
  Time period
- Platform info
- Download
- Data view



http://www.marineinsitu.eu/dashboard/

CMEMS IN SITU TAC

IN SITU TAC ORGANIZATION Leader: Ifremer / France

Management & Operations
7 Regions

Global:	Ifremer / France
Arctic:	IMR / Norway
Baltic:	SMHI / Sweeden
NWS:	BSH / Germany
[illegible]:	Puertos del Estado / Spain
MED:	HCMR / Greece
Black Sea:	IOBAS / Bulgaria

Scientific Expertise Cross Cutting

Product Quality:	Oceanscope-PdE-IMR
Multi Year:	SOCIB-OceanScope-PdE
BGC assim.:	IMR

System Evolution

HF Radar:	AZTI-CNR-SOCIB
Carbon Data:	UIB
BGC assessment:	IMR-HCMR-SYKE
Monitoring:	SOCIB-PdE-HCMR

Figure 2.1 : The In Situ TAC components.

Multiple platforms

International and regional organizations

NRT (Near Real Time) products

REP (Reprocessed) of delayed mode products

From CMEMS-INS-QUID-013-030-036.pdf

CMEMS IN SITU TAC

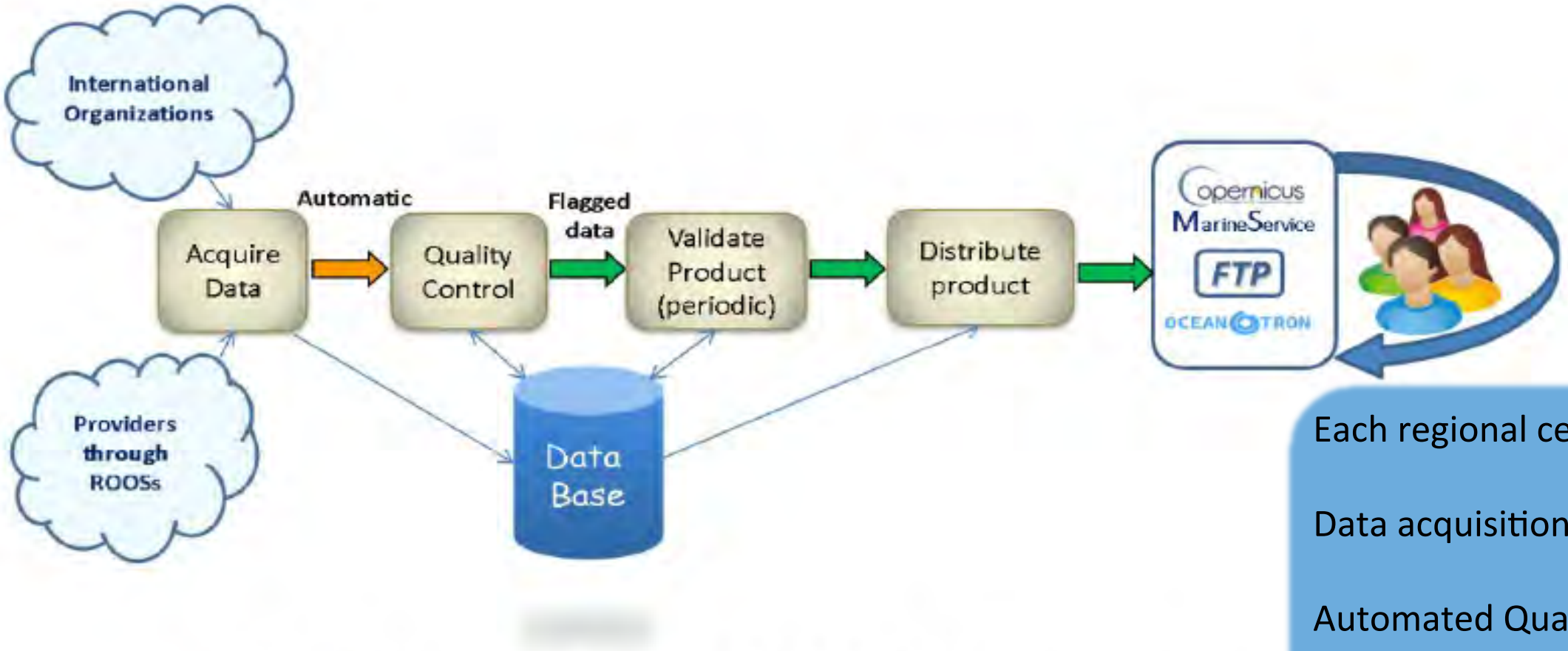


Figure 2.2: Functions implemented by the In Situ TAC components

Each regional center:

Data acquisition

Automated Quality Control

Product validation

Product distribution

From CMEMS-INS-QUID-013-030-036.pdf

QUALITY CONTROL: 2 STEPS

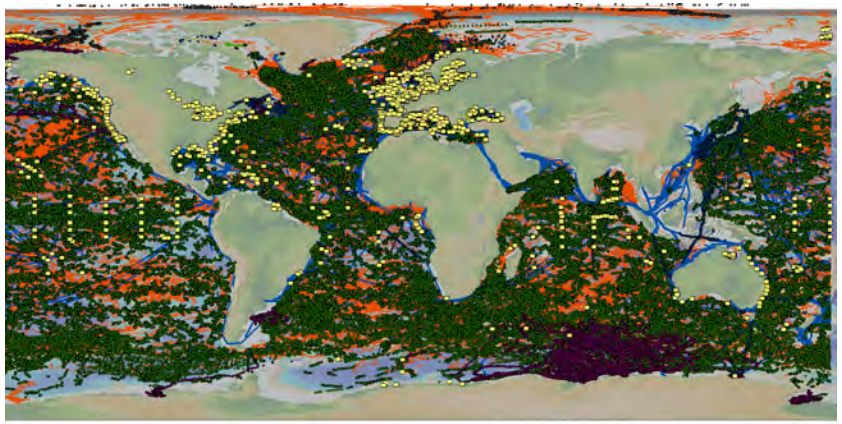
STEP 1:
Automated NRTQC

Code	Meaning	Comment
0	No QC was performed	-
1	Good data	All real-time QC tests passed.
2	Probably good data	These data should be used with caution
3	Bad data that are potentially correctable	These data are not to be used without scientific correction.
4	Bad data	Data have failed one or more of the tests.
5	Value changed	Data may be recovered after transmission error.
6	Value below detection/quantification	The level of the measured phenomenon was too small to be quantified/detected by the technique employed to measure it. The accompanying value is the quantification/detection limit for the technique or zero if that value is unknown
7	Nominal value	-
8	Interpolated value	Missing data may be interpolated from neighbouring data in space or time.
9	Missing value	-

Table 4 Quality control flags.

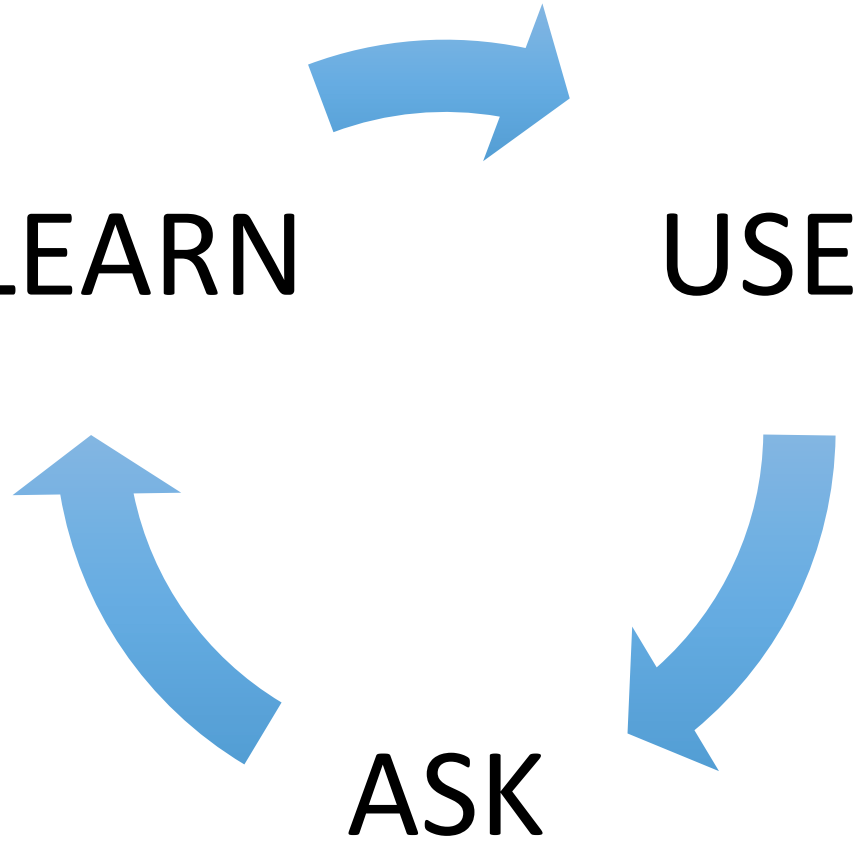
STEP 2:
REP: Area dependent metrics, including

1. Visual quality control.
2. Comparison to a reference climatology.
3. Objective analysis and residual analysis.
4. Assessment of drifter data.



From CMEMS-INS-QUID-013-030-036.pdf

MARINE DATA



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